APPLIED SCIENCE

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

■

Vol. VI - New Series

■

May to October
1912

■

PUBLISHED BY
THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

ENGINEERING BUILDING
UNIVERSITY OF TORONTO, CANADA

INDEX VOL. VI.

Applied Science

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Old Series Vol. 24 MAY, 1912 New Series Vol. VI., No. 1

STEREOGRAPHIC MEASUREMENT

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The problem of deducing measurements from a photograph is the inverse of that of producing a perspective drawing from the known dimensions of an object, for the image produced by the lens on a photographic plate is a true perspective if the lens be free from spherical aberration and astigmatism.

If the plate be assumed vertical then the nodal point of the lens is the point of view, the plate is the picture plane, and the focal length of the lens is the distance line. The optic axis of the lens intersects the plate in the principal point and a horizontal line drawn through this point is the horizon of the perspective. Having given the horizon line of a photograph the principal point and the distance line, that is the focal length of the lens, the problem of estimating the object in all its parts is, however, indeterminate, for we have two unknown quantities, viz., the distance of the object and its dimensions, which are dependent on each other. But if we are provided with two perspectives of the same object from suitable stations, the problem may be solved by plane table methods.

The use of photographs in surveying dates back as far as 1858 or 1859, about which time Colonel Laussedat executed numerous experimental surveys with the camera, the results of which were communicated to the Academy of Sciences and received the endorsation of that body. Subsequently the method was taken up by Meydenbaur in Germany, and was used to some extent in military work during the Franco-German war, later it was exploited by Finsterwalder, Koppe, and others. It was also used in Austria, Sweden, Switzerland and Italy during the seventies and eighties. Perhaps the most extensive work by the photographic method was in the Rocky Mountain survey and the Alaska boundary delimitation (Canadian section) under Deville, Surveyor-General of Dominion Lands; this work was begun in 1888 and continued up to about 1897, and was most successful.

In all this work extending over a period of 30 or 40 years, the methods employed for reduction of the photographs, though differing much in detail, were all what may be fitly termed "monocular"; that is to say, a single photograph was in itself a unit and the determination of any magnitude was arrived at by the comparison of two or more units. The various methods are all somewhat intricate and laborious, and, moreover, the identification of terrestrial details as viewed from two or more stations at different angles is often very difficult. Again, the method is not self-contained, for the camera

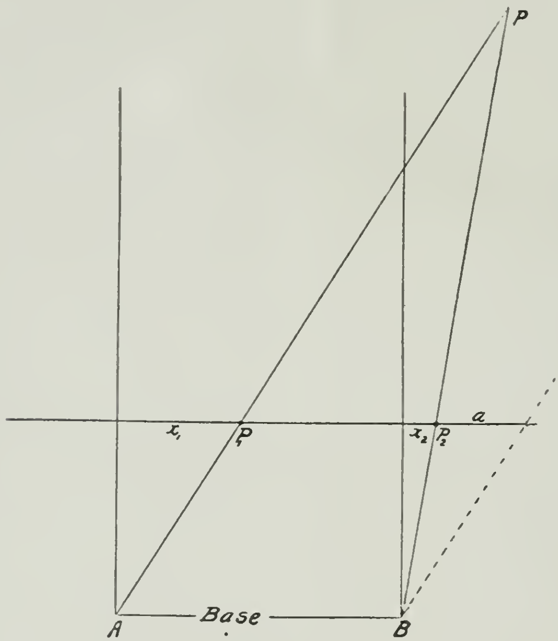

FIG. 1.

stations and other control points must be determined by triangulation or other extraneous method.

This plan of taking a single photograph as a unit is analagous to that of a man who views an object with one eye closed and then moves to a new view point and makes a similar observation, instead of using both eyes from one station. It seems all the more remarkable that the binocular method was not introduced when the plastic properties of a stereograph were so well known, for the invention of the stereoscope dates back to 1838.

The first suggestion of utilizing stereoscopic photographs for measurement of distance by means of a comparator seems to have been made by Dr. Pulfrich of the scientific staff of the Zeiss works, in 1901. (See "Naturwissenschaftliche Rundschau," 16, page 589.)

From that time on numerous articles have appeared in scientific periodicals dealing with the problem, and meantime the firm of Carl Zeiss has steadily improved the original apparatus until a permanent form of both camera and comparator have now been reached, both of which are of great perfection.

In this paper I purpose to deal with the question of measurement only, assuming that means have been used to secure accuracy in the setting of the camera.

Consider a single photograph and let lines be drawn on it representing the horizon and principal line of the picture. This will divide the photograph into quadrants and the co-ordinates x and y of any point therein may be measured by means of a comparator. The actual values of these quantities cannot, however, be determined until their distances from the station are measured and this distance may be obtained from a stereoscopic pair.

The method of measuring the depth of field to any point from a stereograph requires a linear measurement of the parallax of that point. The relation between parallax and depth of field may be illustrated by the accompanying diagram, Fig. 1.

Let A and B be the two points of observation, and let P_1 and P_2 be the images of the distant point P on the picture plane, then x_1 is the ordinate of left image, and x_2 of the right and the difference between AB and P_1 P_2 is the parallax and is obviously equal to $x_1 - x_2$. Let the parallax be denoted by a, equal to the algebraic difference of the ordinates. It is clear that when the parallax a equals O the point P must be at infinity, and that ^{h} increases as P approaches AB, also that all points lying on a vertical plane through P parallel to AB have the same parallax.

Fig. 2 exhibits the parallax of various points in an actual stereograph. The base of the pair of photographs was 2.438 m. and the focal length of the lens was 141 mm. As the picture is mounted the base in represented by a distance of 145 mm., and the distances between various pairs of points are shown on the figure, from which it is seen that the nearer the points lie to the station the greater the parallax. It must be observed, of course, that the parallax is not a measure of the distance directly to the distant point, but a measure of the perpendicular distance between two vertical planes, one of which passes through the station points and the other through the distant point parallel to the first, in other words, the "Z" of a rectangular system of co-ordinates.

In the taking of the photographs it is necessary that the plates be vertical and that they lie in one plane; the stations may be on the same or different levels. The length of the base and the focal length of the lens are required. By convention the left station may be conveniently taken as the point from which measurements are to be made, hence the co-ordinates x and y will be measured from the left plate and the parallax from both.

It now remains to show how the actual co-ordinates of a point in space may be determined from the co-ordinates as measured on the stereograph. In Fig 3:

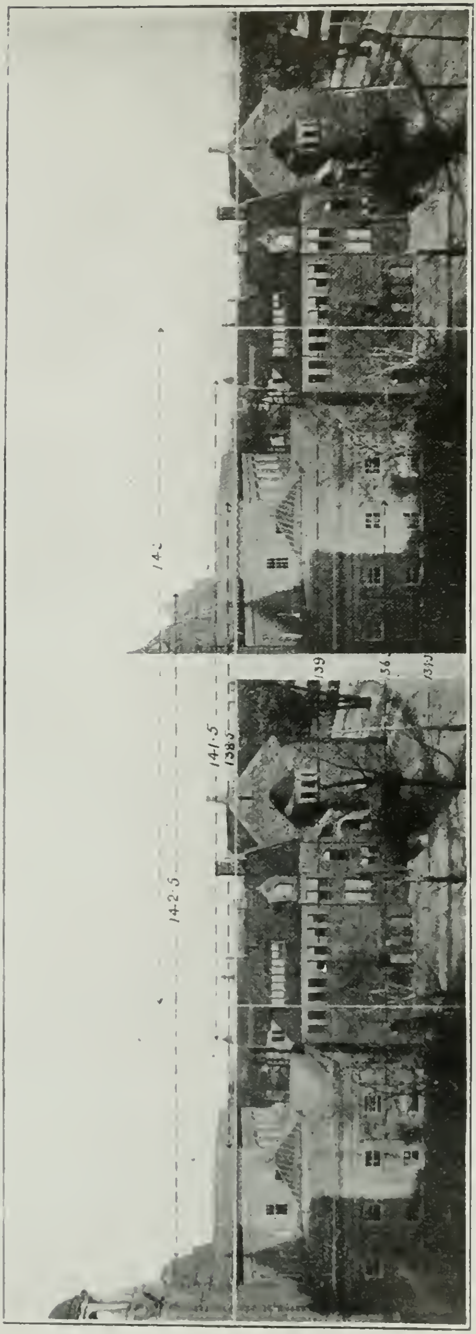

Fig. 2—Base = 2.438 metres, f = 141 mm.

Let P be the point whose position is to be determined, and which is represented on the plates by the images P_1 and P_2; let the ordinates of these points be x and x^1, (x^1 being negative), let B be the base and f the focal length of the lens. Then, from similar triangles it is evident that Z, the distance of a plane through P = B

$$\frac{f}{x + x^1} = B\frac{f}{a} \text{ also } X = Z\frac{x}{f} \text{ and } Y = Z\frac{y}{f}$$

Fig. 4 shows the latest model of the stereo-comparator destined for the precise measurement of stereographs, one of which has lately been added to the photographic equipment in the University of Toronto. The instrument is provided with a binocular micro-

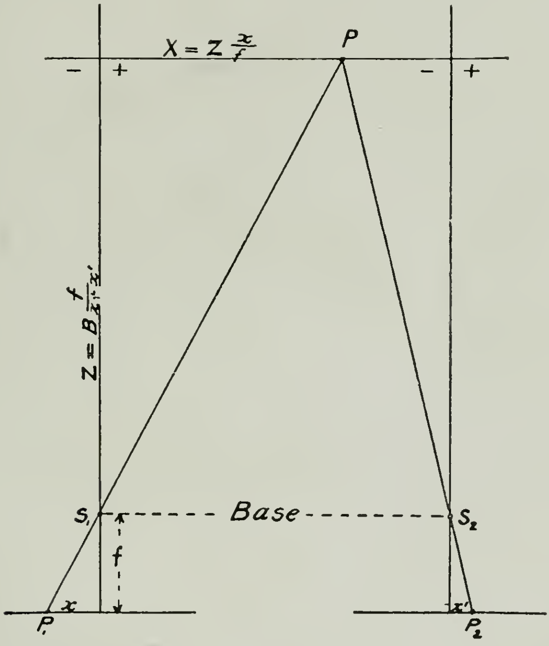

Fig. 3

scope magnifying eight times, of which the objectives are shown by O_1 and O_2, the eye pieces by E_1 and E_2. The microscope may be focussed on the plates by a screw not visible in the figure, and the eye pieces may be separately adjusted to compensate differences in the eyes of the observer and are also adjustable to different interocular distances.

The plates P_1 and P_2 are rigidly held in place by metal clamps, and are illuminated from beneath by adjustable mirrors M_1 and M_2. Each plate may be rotated in its own plane by screws S_1 and S_2, so

that the horizons of the two plates may be accurately adjusted. Also the right plate P_2 may be removed parallel to its length by the screw H so as to compensate for difference in level of the two stations. In the optical planes of the microscope are two balloon marks, which appear to coincide when the instrument is in accurate adjustment, and may be set so as to apparently coincide with any point on the stereograph whose position is required.

The screw A moves the entire bed plate, carrying both plates to the right or left, and its movement is indicated on the scale X, the screw B moves the microscope at right angles to the bed plate, and its motion is indicated in the scale Y, and the screw C moves the right plate to the right or left independently of the other plate, and its movement is indicated by a scale and divided screw head Z.

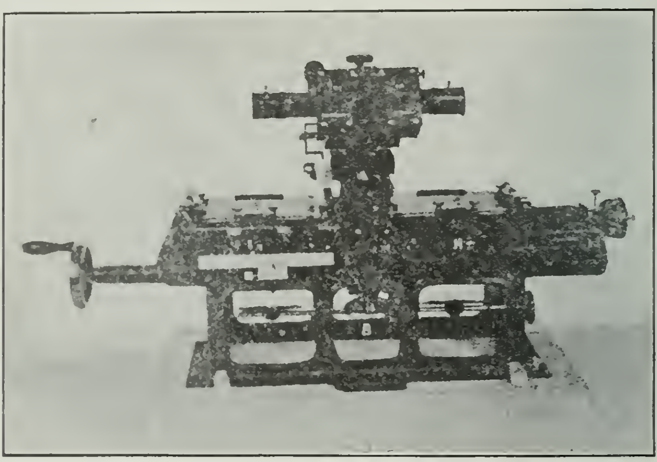

Fig. 4.

All three scales read to 1-50 mm., and by estimation to 1-100 mm. Thus, by means of the scale X the distance of any point to left (+) or right (—) of the optic axis is measured by means of Y the height of any point above (+) or its depth below (—) the horizon is measured, and lastly, by means of Z the parallax of any point is determined. From these three measurements made on the photographs the actual co-ordinates in space are at one determined by means of the simple formulas already given.

The great simplicity of this method as compared to that of plotting by means of the plane table will be at once apparent, and the decision secured is much superior and comparable to that of any other method of survey in ordinary country, while in mountainous dis-

tricts it ensures results that cannot otherwise be secured except at very great cost.

The application of photogrammetry to stereographs is not confined to survey work alone, but may be used for any purpose where measurement is required. For example, if two cameras are used and simultaneous exposures are made the method becomes applicable to moving objects, and may be employed to indicate the position at any instant of military forces during manoeuvres in the field or of vessels at sea, or to determine the altitude of clouds, aeroplanes or the flights of birds. In a similar way the method becomes readily applicable in astronomy. In architecture it may be employed to examine and measure details which are not readily accessible. Again, the method may be modified by taking two photographs from the same point at different times when any changes in the view will be at once made evident, this will find application in estimating relatively small changes, such as glacier motion, local variations in contour of the earth's surface, subsidence of structures, progress of earthworks, etc., or in the detection of spurious coins or counterfeit bank notes.

FOUNDRY IRON

By M. L. Smith, B.A.Sc., '11.

But little more than a decade ago this subject could have been considered in its entirety in a very few words. For centuries iron has been known and worked with little noticeable improvement in the methods employed, which was probably due to the fact that it was chiefly used for the making of fine steels.

The nineteenth century has been most appropriately named the "Iron Age," but it is more likely that the increased and more improved facilities for mining and handling have had more influence on its widespread adoption than has a knowledge of the metal itself.

The layman knew that it could be melted and that it would permanently retain the form of the mould into which it was poured and allowed to solidify. The founder knew, further, that certain combinations of pig and scrap made much better and stronger irons than others, that certain forms of castings would give way under shrinkage stresses, that gases were generated by the hot metal in the mould that must be provided for, and many other mechanical details which amounted to very nearly the extent of our present knowledge.

During the century it may be said that the methods of working evolved from the most primitive methods to those directed by the foreman governed entirely by rules of thumb and hearsay along with dearly bought experience.[1]

Then, with the coming of the twentieth century there sprang

1. "Native Iron and Coal Working in the Province of Shansi," China. *Engineering*, December, 1910. pp. 761.

up with mushroom rapidity, a school of young technical metallurgists who, without foundry experience, came forth with the cry that chemical analysis was the only way to ensure success. Practical metallurgists of mature experience have found that, although chemical analysis is very important when considering problems in cast iron, it is only one of the agents to be taken into account, and "such is the nature of the metal that is is impossible to predict with certainty that positive physical results will follow a given analysis."

In fact, one of the greatest strides in conducting a foundry plant successfully has been the recognition by owners and managers of the value and importance of chemistry in connection with the mixing of iron and its intelligent use in conjunction with physical tests to obtain desired properties in castings.[1] With the aid of the chemist it is known what goes in with his aid and by physical tests it is known what comes forth. The last and greatest step towards the gaining of combined physical and chemical knowledge however, has taken place within very recent years, assisted chiefly by the improved electric furnace, the introduction of the thermo couple by Le Chatelier, and the application of the microscope to the study of iron and steel, which first appeared in a paper by Sorby. Professor Turner also, in 1906, devised a simple instrument for correlating both volume and temperature of changes. So that the last five years have seen more investigation and research, as well as the production of more literature on the subject than has ever been seen before.

It may be said that the physical properties of the compound known as cast iron depend upon three things, viz.: the temperature to which it has been raised; rate of cooling, and chemical combination. The first two, in practice, depend more or less upon the last. Pure cast iron consists of iron and carbon which may be in the form of a graphite, or a carbide (Fe_3C). Compounds of over two per cent carbon are known as cast irons, all lower than this are classified among the steels.

The effect of the metalloids, viz., silicon, sulphur, manganese, and phosphorus, is nearly always indirect, and is in proportion to their effect on the condition of the carbon in the iron.

Silicon

The most generally accepted effect of silicon upon cast iron is that it causes the precipitation of graphite carbon by decomposing the carbines.

Charpy and Grenet had observed that the separation of graphite from originally white iron began at a temperature which was the lower the greater the percentage of associated silicon.[2]

The primary carbo-silicides are exceedingly unstable and are the first to decompose into graphite and silico-austenite. It is

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1. See R. H. Palmer, *American Machinist*, Vol. 25, pp. 1749.
2. Thomas Kennedy, *Engineering*, July 22nd, 1910, pp. 140.

evidently the exceedingly unstable character of the silico carbide which is responsible for the greyness of commercial cast iron.

The effect of silicon upon the temperatures of solidification and recalescence are well shown by some extensive experiments of Mr. Arthur Hague, in which he designates the three arrest points by H_1 H_2 and H_3[2]. Some of his results are shown in Fig. 1.

The first arrest H_1, indicates the commencement of solidification. It is liable to inaccuracies and in some cases it is not definitely shown. The second arrest H_2, is a very definite one and indicates the solidification of eutectic. The third arrest, H_3, also a very definite one, corresponds to the recalescence or pearlitic point.

Turner showed that, in a pure white iron, there is no initial expansion but only a slight lag in the normal contraction. When a

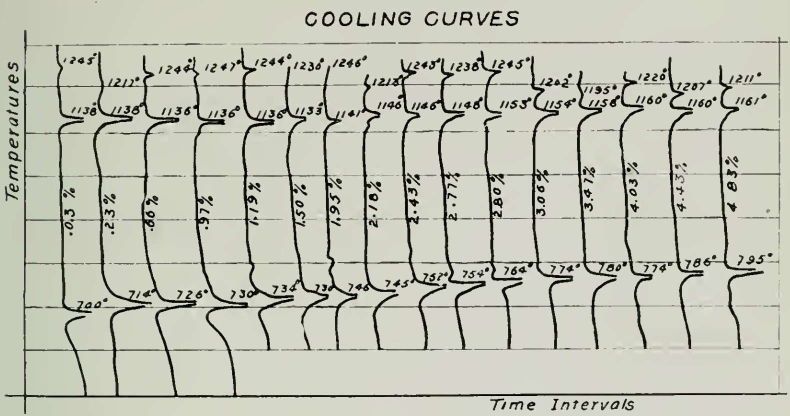

Fig. 1.

relatively small amount of silicon is present there is a distinct expansion at solidification, which occurs during H_1 and persists until the metal is solid or till the end of the eutectic arrest H_1. After the metal completely solidifies, it begins to contract, and the contraction is normal until the third arrest H_2, when a more or less pronounced retardation in the contraction occurs. There is a more or less critical point between white and grey, and the greatest expansion seems to accompany the largest graphitic flakes, which occurs with a content of about 1% to 1.5% of silicon. After this percentage expansion is more or less constant but graphite flakes are more numerous and smaller. An increase of silicon lowers the temperature of the first arrest point H_1; raises H_2 slightly and raises H_3 very much. Thus the effect of silicon present as silico-ferrite or silico-cementite is to raise the temperature of the point at which carbide separates out, i.e., to increase the range of stability of alpha iron.

1. Arthur Hague, B.Sc., *Engineering*, Vol. 90, pp. 841.

The experiments of Professor T. Turner and A. Hague referred to in the above paragraph, corroborate generally the results of Mr. Hague.[1] Mr. Turner found that the effect of silicon is to raise the period from 700°C with no silicon to 750°C with 5 per cent silicon. The eutectic arrest showed very small but regular increase from 1130° to 1160° over the same range, while the temperature of the first arrest at the commencement of solidification was lowered.

The strength of cast iron does not vary directly with its content of silicon, but nevertheless it seems to follow a continuous curve, as in Fig. 2. This graph, which is the result of many experiments, shows the strongest iron to contain about 2.1 per cent silicon, other elements being in average proportion.

The hardness of pure cast iron increases with additions of silicon

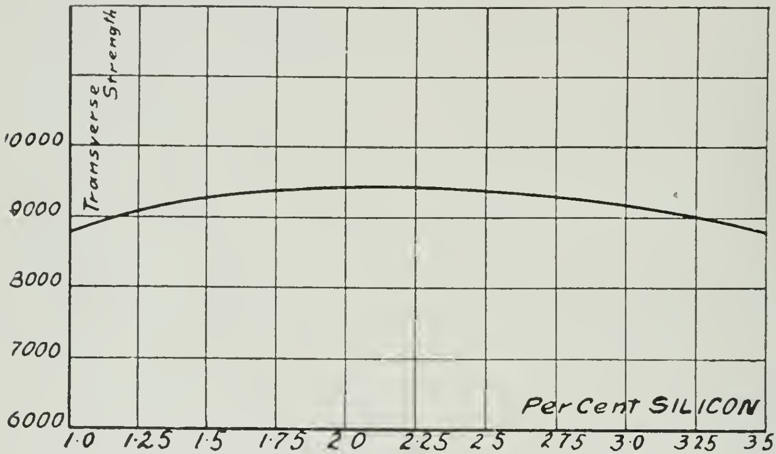

FIG. 2.

up to 1% at which content it is still white. At this point it suddenly decreases after which it is more or less irregular. This is illustrated in Fig. 3.

The progressive influence of additions of silicon in softening iron and preventing carbon from remaining in the combined state decreases more or less rapidly as the silicon increases. The greatest effect is said by some writers to be with content of 1.5 to 2 per cent., but there is a difference of opinion on this point. It probably depends largely upon the amount and character of other elements present.

In general, the presence of silicon tends to accelerate the change from the meta stable carbide to the stable graphite condition. This results in the decomposing of the carbide at a lower temperature, which constantly causes the iron to be softer and greyer.

1. *Journal of Society of Chemical Industry*, 1910, pp. 1160.
2. Transactions of A. S. M. E., Vol. 25, pp. 914. W. J. Keep

Sulphur

The presence of this element lowers the freezing point of the iron, at which temperature the austenite, free from sulphur, is separated.[1] The sulphur at the same time is concentrated in an eutectic of austenite, cementite and a sulphide which solidifies at about 1130°C. In an iron free from sulphur the cementite decomposes with the formation of grey iron. The presence of sulphur, however, produces alternate layers of sulphide and cementite, the sulphide hindering the decomposition of the cementite (carbide), resulting in the production of a white iron. The pearlite point remains practically constant.

Practically, the results of sulphur are shown to be precisely

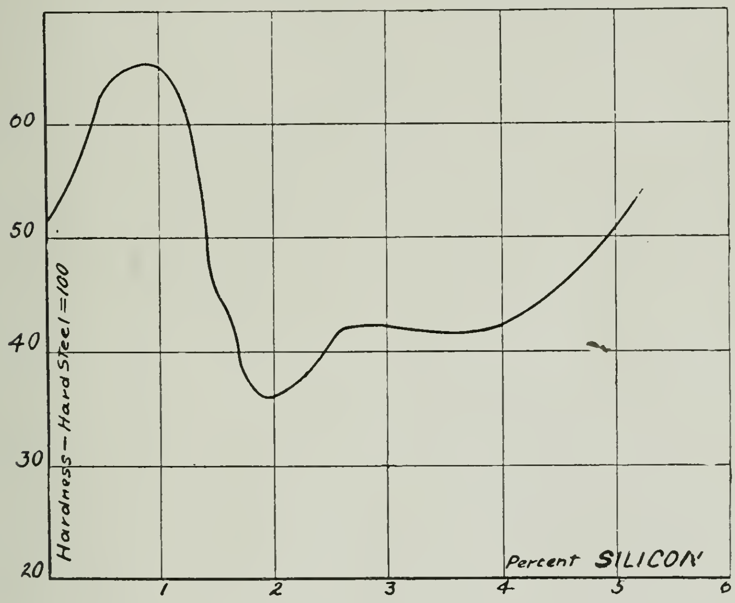

FIG. 3.

opposite to those of silicon, the former having a hardening tendency by throwing the carbon into the combined state. Some attempts have been made to determine the amount of this effect for each fraction of a per cent. of sulphur, but little has been accomplished on account of the various effects of the presence of silicon, manganese and other conditions in different irons.

So far as is known to the writer, not one good word has been said for the element under discussion, and it is certain that all its evil effects are by no means realized. Its ultimate action has been

1 T. Liesching, *Journal of Society of Chemical Industry*, 1910, pp. 1207.

very little investigated, but it is well known to all metallurgical chemists and others who have studied it that its immediate effect is to throw carbon into the combined form. If has, besides, an effect upon the grain of iron that is clearly visible and distinguishable at least in low silicon irons, and this is physically manifested in the weakness and rottenness of irons high in sulphur even when the castings are all grey.

It is in white irons, however, that the most striking difference occurs. The fractures of the two irons, one containing .03 per cent. sulphur and the other .06 per cent., are radically different even when the analysis is the same in all other respects.[1] One of the most objectionable features is the shrinkage it causes and the consequent contraction strains in high sulphur irons. These are best shown by white iron.

When a sample containing less than .04 or .05 per cent sulphur is cooled in water from a red heat, it does not make any sound, no matter if the iron is very low in silicon. An iron much higher in silicon and with .06 per cent. or over of sulphur, however, when cooled in the same way will almost invariably be heard to make a series of clicks as it cools by the formation of cracks generally nearly perpendicular to the length of the sample. These cracks go almost through so that the barest tap against a piece of wood will, in extreme cases break it in two.

The nature and appearance of the fracture of high sulphur iron is entirely different from that of low sulphur iron of the same analysis. In the former, it is entirely flat without any visible appearance of crystals and is quickly disclosed by a film of oxide, while the latter iron has beautiful crystals radiating from every cooling surface, especially from the bottom and the sides.

As the silicon content rises almost as great a difference continues to be noticeable, the low sulphur iron showing a "grain" or grey part at a much lower silicon content than the high. At the same time the high sulphur metal continues to show some white around the edges far beyond the silicon content at which the low sulphur iron had become all grey The look of the grey part, too, is very different; that of high sulphur being fine grained and blue black as compared with the grey of the low sulphur which is much more open in grain.

When sulphur to the extent of about 2½ per cent. is melted with grey cast iron, a portion of the carbon separates in a sooty form and an intensely hard, white metal is produced. With a smaller quantity of 0.3 to 0.5 per cent a mottled iron of considerable strength is obtained, which, when broken, shows a quantity of grey spots enclosed in reticulating lines of white on the fractured surface.[2]

The natural deduction from the above is that, for chilled or white iron castings, foundrymen should not use an iron of moderately high silicon, say .7 per cent and get the desired chilling action by high sulphur of say 0.2 per cent. Instead they should use a low

1. J. E. Johnson, *American Machinist*, Vol. 26, pp. 1451.
2. Bauerman, *Iron and Coal Trades Review*, Vol. 77, pp. 278.

silicon iron if possible, say 0.2 per cent, and a moderate sulphur content (.06 or .07 per cent.) which would give an equal or better degree of chill as well as a casting of less shrinkage and far more available strength. This is particularly true of small and comparatively thin chilled castings. It is impossible, under ordinary conditions of working, to remove sulphur from the iron, but more can, to a great extent, be prevented from getting into it by careful working. Also, under certain conditions it reacts with manganese to form slag. These will, however, be discussed under the headings of "coke" and "manganese" respectively.

"Sulphur is bad, and there is no cure for its effects on castings except to keep it out of the pig and coke. Its effect is such that one point of sulphur will offset about fifteen points of silicon."

Phosphorus

The most generally recognized effect of phosphorus is to increase the fluidity of the iron. It may be used for very intricate castings up to 1 or 1.5 per cent with beneficial effects, but these are high values.

The action of phosphorus in lowering the melting point of iron is well established and it is probable that is the cause of its beneficial action on the fluidity and shrinkage.[1] It is obvious that if the metal stays melted at a lower temperature and the casting is fed from risers there will be a much shorter interval of temperature to traverse in cooling down to that of the atmosphere with corresponding reduced shrinkage. This, however, is by no means the only reason for these effects. The reason why such marked differences exist in shrinkage of phosphoric and sulphur irons has not been at all satisfactorily explained by any of the investigators whose writings are available to the writer of this article.

Phosphorus has been very thoroughly investigated by Mr. J. E. Stead in England and its effects in producing brittleness and unreliability have been clearly shown and reasons for the action discovered, but its effect of producing fluidity is so marked and its action in preventing shrinkage also, that, in cast iron, a metal well known to be brittle even when entirely free from phosphorus, the advantage up to a certain point far outweighs its disadvantages. Just where this point is for the general run of foundry work is hard to determine, but it is probably between 0.4 and 0.75 per cent.

Manganese

The character of this element and its effect upon cast iron has been much investigated by Mr. H. I. Coe and Mr. Stead.[2] The former found, in the case of white cast iron, the curve of expansion showed four minima, vix.:—

1. J. E. Johnson, *American Machinist*, Vol. 26, pp. 1451.
2. H. I. Coe, *Journal of Chemical Industry*, 1910, pp. 1160.

0% Mn, corresponding to the compound Fe C
5% Mn, corresponding to the compound 8 Fe C Mn_3 C
15.3% Mn, corresponding to the compound 2 Fe C Mn_3C
19 % Mn, corresponding to the compound 3 Fe_3C_2 Mn_3C

Manganese appeared to lower the temperature at which the primary crystals separate out. The temperature of the eutectic arrest point is lowered by about 20°C for each one per cent. of Mn, but disappears at ten per cent Mn. Increase up to five per cent also lowers the pearlite point about the same amount. The pearlite becomes finer and more sorbic up to 5%. In the case of grey iron the expansion on solidification is very large. The temperature of solidification appears to rise with the addition of Mg. up to four per cent. Hardness increases up to two per cent, then falls to 2.65 per cent, after which it rises, first rapidly up to 4 per cent, and then uniformly.

The prevailing idea as to the effect of manganese on the condition of the carbon in cast iron is that it exerts an immediate whitening action and that three or four per cent will convert a grey iron into a perfectly white one. Keep, however, gives examples of iron rich in manganese being grey.[1] It has also been shown that the alloy with 8 per cent. of manganese may be definitely grey. Analysis show that although there may be, at first, a slight increase in carbide, the iron contains as much graphite relatively to combined carbon with 2.65 per cent manganese as with one per cent. Beyond carbon with 2.65 per cent. manganese as with one per cent. Beyond this until 19 per cent. the quantity of combined carbon steadily increases. The cast alloy of 30 per cent. is perfectly white.[2]

Manganese increases the shrinkage by making the grain closer. The alloy with 11.15 per cent. has nearly twice the shrinkage as that of one per cent. Mr. Coe gives tables of many analyses to illustrate the progressive effects of manganese upon shrinkage and hardness, but space will not permit them to be cited here. Some crushing tests by Professor S. M. Dixon, of the University of Birmingham, however, are of interest.

THREE GREY IRON SAMPLES:

Bar	Mg.	Height	Thickness	Area	Load
B	1.00	1.25	0.633	0.395	37.34 tons
E	2.65	1.25	0.635	0.398	43.27 tons
F	3.45	1.25	0.638	0.404	46.91 tons

The increase of strength shown is more likely due to the effec of the element upon the grain of the iron than to its effect upon the carbon.

Manganese has a definite effect upon the sulphur content. Mr. Stead proves that sulphur crystallized with manganese as MnS previously to the solidification of the carbon, and that the metal then turned grey on cooling.

1. *Cast Iron*, pp. 100, West.
2. H. I. Coe, *Engineering*, Vol. 90, 99, 581.

From the above, it is evident that manganese increases the expansion upon solidification, but in no definite ratio. The shrinkage increases with increase of manganese, but in no case is it as great as in white irons. It enables a very much larger proportion of carbon to be taken up and retained in the combined state. When free from manganese, cast iron contains little more than four per cent carbon in variable proportions of the graphitic and combined forms.[1]

Manganese up to one or two per cent. is not objectionable on account of any hardness that it gives the iron, and is much more likely to make it soft and prevent chilling of thin edges by its action on sulphur than it is to have the opposite effect on its own account.[2]

IRON MIXTURES

Analysis

The value of analysis cannot be overestimated, and a suitable quiet, clean, and convenient place should be provided for this, at the present time, very necessary department of the plant of any pretentions whatever. Several varieties of pig should be kept in stock and properly stored according to analysis, and analysis of scrap should be taken and recorded from time to time.

The writer does not propose to give the several standard methods used. They can easily be obtained from many excellent and complete text books on the subject, such as "Practical Methods for the Iron and Steel Works Chemist," by J. K. Heess, 1908, and others.

It should be said, however, that much special apparatus is procurable that reduces ordinary analysis to very simple operations. For instance, in the case of cominbed carbon, the sample and a standard iron are dissolved in similar tubes, with equal amounts of dilute HNO_3. The amount of dilution necessary to bring the sample solution to the same color as the standard one gives the required percentage of carbon on the graduations of the tube. For accurate work the hydrogen jet method is recommended for sulphur.[3] A much improved method for general analysis has been devised by Messrs. C. H. & N. D. Risdale quite recently and provides very rapid methods for classes of work where variation is not great.[4] Samples should be taken by drilling several holes through the specimen. The drillings should be well mixed, and the required amount taken.

Mixing

To calculate the mixture three things must be known:—

(1) Analysis of pig and scrap.
(2) The changes that take place in the melting.
(3) The composition of the metal required.

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1. H. Bauerman, *Metallurgy of Iron*, pp. 278.
2. J. E. Johnson, *American Machinist*, Vol. 26, pp. 1451.
3. Randolph Bolling, *Engineering News*, May 7, '08, pp. 505.
4. C. H. & N. D. Risdale, before Iron and Steel Institute, *Engineering*, June 16, 1911, pp. 801.

Changes during melting, depend upon

(1) Construction of cupola.
(2) Pressure and volume of blast.
(3) Composition of coke.
(4) Grade of iron being melted.[1]

Ordinary grey iron containing two per cent and upwards of silicon will lose from 0.2 to 0.3 per cent. silicon during melting. When there is less, the loss decreases and, with 1.5 per cent. there is practically none. Heavy blasts will reduce graphite carbon. Manganese tends to decrease it.

If sulphur is abnormally high, a greater loss of manganese is noticed, due to the formation of manganese sulphate. Sulphur generally increases from 0.2 to 0.38 per cent, except where very pure coke is used. Phosphorus remains practically constant.

Let it be required to find the percentage of silicon in a charge the weights of the irons being known.

Brand	Cwts. Used	Silicon per cent	Silicon Cwts.
A	3	4.00	12
B	4	2.25	9
Scrap	3	2.00	6
	10		27

Now 10 × silicon in mixture = 27

$$\text{then} \frac{27 \text{ (cwts. per cent.)}}{10} = 2.7 \text{ per cent silicon}$$

2.7 — .249 loss in melting = 2.451 per cent. silicon in casting.

Suppose the composition of pig and scrap available are given and metal of a specified composition is required, say 2.451 per cent. silicon.

2.451 × .249 loss in melting = 2.7 per cent silicon to be in the calculated mixture. (1) To make up a charge of 10 cwts. of the two pig irons. "B" containing 2.25 silicon is the lowest. "A" containing 4.00 is 1.75 above it. The required content is 0.45 above "B".

Now weight of the 4 per cent silicon iron × 1.75 = 10 cwts. required iron × 0.45 or weight of 4 per cent. iron required = 4.5 ÷ 1.75 = 2.57 cwts.

Weight of iron containing 2.25 per cent. silicon = 10 — 2.57 = 7.43 cwts. This may be checked up by calculating the silicon content of the mixture as has been explained.

2. To make a similar charge containing, in addition to the pig. 30 per cent. scrap, which has a silicon content of 2 per cent. 10 cwts. charge at 2.7 per cent. = 27 cwts. per cent. 3 cwts. scrap at 2 per cent furnish 6 cwts. per cent. 7 cwts, of two pigs must contain 27 — 6 = 21, or average of 3 per cent. Pig "B" has 2.25 per cent.

Pig "A" has 4 per cent, is 1.75 above "B" 3 per cent. desired is .75 per cent. above "B."

Hence cwts. "B" × 1.75 = 7 cwts. × .75 = 5.25 5.25

1. Geo. Hailstone, in *Iron and Coal Trades Review*, Vol. 77, pp. 2,707.

÷ 1.75 = 3 cwts. "B" required 7 — 3 = 4 cwts. "A" required. May be checked up as before.

Any number of similar examples could be given showing it a very simple matter to mix any number of varieties to get a desired content of any one element. It requires a more complicated calculation to obtain the desired quantities when all the ingredients are specified. However, it will be found that there may be a number of combinations that will give the proper content of any one element. These may be worked out for other elements and the best combination selected. If uniform melting conditions are maintained, it will be found easy to obtain a combination accurate to specification within 0.1 per cent in all elements.

Of the physical tests, those of cross breaking and tension are most important. One of the chief tests to a foundryman is that of shrinkage.

That of Keep consists of casting two one-half inch squares bars twelve inches long between the ends of a metal yoke.[1] The shrinkage is measured when the bars are cold by inserting a tapered scale between the yoke and the end of the bar. The yoke is made fairly heavy so that, by breaking the end of the bar the chilling action can easily be seen. The basis of this system is the influence of silicon on the carbon in iron causing the carbon to go from the combined to the graphitic state during cooling. Provided the iron contains sufficient carbon for the silicon to act upon, the quantity of silicon to be added can be varied to produce grades of iron in which any proportion of combined carbon and graphitic carbon can be obtained. It is asserted that if equal amounts of shrinkage exist in different specimens, the silicon and other elements are exerting similar influences upon the carbon, and that the specimens possess similar qualities as regards strength and hardness, also that the amount of shrinkage is a measure of the proportion of silicon present.

Keep's system gives the following results:—

Stove grate iron	.12
Medium sized ordinary work	.14
Maximum transverse test	.16
Maximum tensile test	.18
Grey mottled foundry iron	.20

The above tests are useful signs of the workability and to a certain extent the strength of iron in cases where the sulphur content of the coke and metal are fairly constant.

Testing machine is required only for tensile and cross-bending tests and may be quite simple. There is practically no extension in cast iron yet, much can be gained from the tensile test. The transverse test, the oldest one of all, however, is much more useful, as it includes the capacity for deflection before fracture, which is a property of much utility. The standard test bars are two inches by one inch, and twelve inches long. Results depend largely upon

1. See F. J. Cook, *Iron and Coal Trades Review*, Sept. 11, 1908, Vol. 77. also Joseph Horner, *Engineering*, Jan. 13, 1911, pp. 47.

whether they are poured with the casting or separately, whether poured horizontally or vertically, how cooled, relation of thickness of test bar to thickness of casting, whether, if cast on edge, lower or upper edge is placed uppermost in the machine, and a great many other conditions that make the judgment of the operator the primary factor in the usefulness of the tests.

Hardness is usually tested in castings to be machined by recording the number of revolutions of a standard drill required to drill a hole of a given depth. The scleroscope is used most in scientific work and compares the hardness of the sample to that of hard steel, which is rated at 100. The capacity or tendency of the iron to develop shrink holes and spongy places is measured by casting samples shaped like the letter K, breaking them at the junction of the arms and comparing them with the set of graduated samples. If there is any such tendency in the iron it will be seen at the junction of the arms.

Working

The construction of the plant and machinery is hardly within this scope of the article. It may be said, however, that the main factors are convenience and progressiveness of operations. The cupola should be so constructed that the tuyeres flare out towards the inside so that as much air may be blown in at low pressure as possible so as to prevent oxidation and hardening effect and give high temperatures. A large receiving ladle should be provided in which the metal may stand before being poured to allow occluded and generated gases a chance to escape as well as to permit reactions between manganese and the sulphur, etc., and also permit the addition of deoxidating and other agents.

It is important to provide means of drying certain parts of moulds and thus induce more uniform cooling of castings.

Blast pressures are also very important factors, and, in order to govern quality of product, they should be kept constant.[1] Normal pressure is from .75 to 1 pound per square inch. This means from 21 to 28 inches of water. Gauges are fitted to most modern cupolas. Blast must supply about 650 cubic feet of air per minute per ton of iron. The term "belting ratio" is very indefinite. Depends on the character of the blast and fuel, the nature of the casting produced —light or heavy, proportion of wasters, duration of cast, etc. 10 or 8 to 1 represents good average practice.

Probably the most important mechanical agent affecting the condition of the carbon as far as the working is concerned is the rate of cooling. It has been shown that, if the rate of cooling be slow enough there will be a precipitation of graphitic carbon under almost any other conditions. The late Sir Lowthian Bell cast a 6-ton block of white iron to prove that, by slow cooling, there would be a precipitation of graphite at the centre. On the other hand, by suitable chilling, iron of almost any silicon and carbon content may be made perfectly white. The effect of different thicknesses

1. Joseph Horner, *Engineering*, April 27, 1910, pp. 539.

and consequent different rates of cooling was shown by Mr. W. H. Hatfield by casting a block 6 inches square on one end, about 2 feet long and tapering to a thin edge at the other end. All degrees of hardness were obtained in the one casting from coarse grey at the large end to hard white at the other end.[1]

The following experiment of Mr. W. J. Keep goes far to show the difference in physical properties of iron taken from different parts of the same casting which are primarily due to different rates of cooling.[2] A block of cast iron nine inches square and eighteen inches long was cut longitudinally in nine pieces and test bars 1.13 inches in diameter were turned from each piece. The average tensile strength of the bars was—

25,100 pounds	-	from the corners
19,913 pounds	-	from the sides
15,730 pounds	-	from the centre

Very few realize that a variation in the size of a casting causes a greater variation in its strength than would a variation of the chemical composition. The following tables may be taken as reliable results of tests in tension and compression to show the average properties of the irons named.

Next to rate of cooling in effect upon the condition of the carbon should be mentioned the temperature to which the iron has been raised in the furnace. Most agents that tend to produce combined carbon tend to lower the melting point. The higher the furnace temperature, the more refractory the product becomes and the larger the graphite flakes upon cooling.[3] Also the amount of carbon that can be absorbed by the metal is increased as this temperature is raised.

A fairly free use of fuel is desirable where quality of castings is a primary consideration. Along with a little limestone—50 to 60 pounds per ton—a much more fluid slag is produced, which tends to fall down through the fuel instead of clogging the cupola and by floating on top of the iron, protects it in a large degree from oxidation. The higher temperature also permits a freer evolution of gases. The manganese silitate and manganese sulphate can carry the oxides and sulphur to the slag much more easily than in a moderately cold iron. Besides, it is much easier and more beneficial to allow iron to cool if too hot than to increase its fluidity by adding phosphorus or other agents in the ladle.

Coke

In furnaces where the fuel and metal are mixed, certain constituents of the former are transferred to the latter. For this reason as well as the effect upon slagging and heating qualities, all receipts

1. *Engineering*, May 19, 1911, pp. 670.
2. Transactions A. S.M. E., Vol. 25, pp. 914.
3. E. Adamson, *Engineering*, Oct. 13, 1911, pp. 507.

of coke should be analyzed and unsatisfactory lots rejected. Accepted article should not contain more than 8 per cent. ash, not less than 88 per cent. fixed carbon, and on no account, more than 0.75 per cent sulphur, and if even 0.3 per cent. sulphur were specified, the advantages derived from its use would far outweigh its extra

TABLE X

No. of Series	Crushing Tests	% CdC.	% Si	Comp at load of			Max.
				14000	16000	22000	
	Soft steel.	0	0	.00295	.00345	.00490	44200
17	0 White C. I......	2.85	0.81	.00400	.00465	.00645	123520
19	0 Car Wheel C.I.	0.99	0.72	.00570	.00650	.00955	61211
18	0 Heavy Mach.	0.52	2.09	.00330			
13	0 Stove Plate.....	0.10	3.22	.00730	.00855	.01325	48960

No. of Series	Tensile Tests	% CdC.	% Si.	Extensions at load			Max.
	Soft steel			.00305	.00365	.00525	58320
17	0 White C.I.......	2.89	.81	.00400	.00460	.00645	24000
19	0 Car Wheel.......	.99	.72	.00310			30000
18	0 Heavy Mach..	.52	2.09	.00500			24000
13	0 Stove Plate.....	.10	3.22	.01460	.01995		16850

cost. Hard coke is likely to have more ash than soft, and it is usually the case that greater ash means greater sulphur content.[1]

Sulphur limit is generally placed at 0.5 per cent. Suppose one coke to have 0.5 per cent. more sulphur than another. If all the sulphur in the coke went into the iron and the melting ratio were ten to one, the increase, in the metal tapped out would be .05 per cent. in one case over than in the other, an amount equal to the original specified limit of the pig iron. Of course, not all the sulphur in the coke goes into the iron, but often the greater part of it does and is worthy of consideration.

In general, the requirements of a coke are:—[2]

(1) Should be strong and hard so as to resist disintegration in transit and crushing by weight of the charge. Many small pieces are likely to get mixed with the slag and cause "choking" of the furnace.

(2) Should be dense. This determines the ease with which coke ignites and the freedom with which it burns. The denser the carbon the higher the blast pressure that can be employed. Soft coke loses strength rapidly as it is heated and is more liable to crush and interfere with working of the furnace. Density of the mass also determines the concentration of heat possible. Thus, dense coke yields high local temperatures by using more of the air blown in in smaller compass. With lighter coke the heat is more

1. J. E. Johnson, *American Machinist*, Vol. 26, pp. 1451.
2. E. L. Rhead, *Engineering*, July 15, 1910, pp. 107.

diffused and the melting zone rises further above the tuyeres. For hard coke it would be better to have the air come in to the furnace tangentially so in order to retain it as long as possible in the melting zone.

(3) Should have a good cell structure.

(4) Should be as free as possible from ash.

(5) Should be uniform in texture.

Non-uniform coke is as bad as soft coke. It is extremely hard to regulate the blast and the consumption is increased when it is used.

Ash makes the coke poor, necessitates more flux and often contains iron pyrites, which is very high in sulphur.

Coke giving a red ash is more likely to contain a larger percentage of sulphur. The red color is due to oxide of iron (ferric oxide) produced by burning off the sulphur from the sulphur of iron and converting the iron into oxide. If it gives a white ash it is likely to contain little sulphur although the element might be present as sulphide of lime. If iron, during melting, come in contact with iron sulphide, it will, in most cases, dissolve and take it up. Other sulphides may be decomposed and the sulphur taken up by the iron. These additions are very hard to prevent if the sulphur be in the coke. The production of an easily fused slag that will run freely greatly favors the passage of sulphur into the slag and sufficient lime should be used to effect this. The use of fluorspar assists in producing fluidity and presents the lime in a suitable form to attack the sulphide of iron. Viscous slags of a cindery nature favor the passage of sulphur into the metal. High melting temperatures produce greater fluidity and quicker separation of the metal and consequent less absorption of sulphur. This, of course, means that better coke, even though as much sulphur may be present as in inferior kinds, will do less harm to the metal. Thus, increased temperature favors the exclusion of sulphur and phosphoric pig of lower melting point and greater fluidity are less affected than refractory irons that melt sluggishly. Similarly slow-working and hanging of the furnace will tend to more sulphur.

Sulphur is present as sulphide of iron, calcium sulphate and possibly other forms. Its presence is easily detected by the odor of rotten eggs (H_2S) produced when burning coke is quenched. Sulphur dioxide is also given off in burning but is less easily distinguished. Thus, it is seen that other qualities than low sulphur in the coke contribute to low sulphur in the iron.

Iron for Particular Uses

There is no doubt that iron can be made much more satisfactory if its use and condition of employment be known, both by special treatment and suitable chemical composition. Tests have shown that the harder metals are stronger in compression than the softer ones. The latter, however, give greater deflections, are tougher and are more suitable for parts subject to shocks. For very close grained gas engine work the grain should be as fine as possible without

making the castings too hard. This means low melting temperatures and often the composition known as "semi-steel" is used for this purpose. Some purposes require certain combinations. For instance, the best mixture for making enameled ware is given as carbon 3.5 per cent, silicon, 2 per cent., phosphorus, 1.5 per cent., and manganese 0.6 per cent. by the best German authorities. For chemical plants, Professor Daniell showed by many experiments, that grey iron is attacked three times as rapidly as white.[1] Thus, in cases where tanks to contain H.Cl are required, it is best to cast them around collapsible chills, thus obtaining a backing for the white iron to give the necessary strength.

Summary

There are a few simple rules that should be remembered as the basis of working knowledge. The different agencies that affect the quality and properties of the product overlap in their effects, sometimes neutralizing and sometimes accentuating one another. Hence, in order to control the output, most of these influences should be kept constant. The introduction of chemical analysis has made possible the elimination of one, for a long time very troublesome variable.

It is well to bear in mind, that for a given composition, the smaller the particles of graphite the stronger the iron. A cast iron of maximum strength should have a metallic matrix of maximum strength, which means that the matrix should consist of pearlite or with but a slight excess of cementite which, in turn, means that the combined carbon should be somewhere between 0.7 and 1.0 per cent.[2] These, and many similar conclusions may be deduced from the foregoing article.

The steadily advancing cost of labor as well as sharpening competition is greatly increasing the necessity of reliability in the production of castings. The percentage of "westers" allowable is becoming less each year, and, in fact, is required by most firms to be reduced to a minimum. For these and other reasons, the chemist and the testing plant are as necessary to the foundry as is the raw material. Nevertheless the long experience and practised eye are even more essential to the man in charge than ever before, for, as has been shown, the results of tests and analysis are always qualified by a host of conditions all of which must be taken into account. The effect of research has been to deduce a cause for each property, queer or otherwise, belonging to the iron. So that, while machinery and appliances have greatly simplified actual operations: to say nothing of the quickness of decision and promptness of action necessitated by the nature of the operations involved, keenness of perception and soundness of judgment must always be the primary requisite qualities of the "man behind the gun."

1. F. J. R. Carulla, in *Iron and Coal Trades Review*, Vol. 76, pp. 1951.
2. W. J. Keep, Transactions American Society of Mechanical Engineers, Vol. 26, pp. 483.

AT THE CLOSE OF THE COLLEGE COURSE

By J. Lanning, '11

Free, free, free—the one word in the whole realm of thought which can give expression to the idea uppermost in the student mind of the Fourth Year Class, as the echoes of "farewell" cheers grow fainter and fainter, and finally die away along the corridors of the various examination halls, when the last paper for the degree of B.A.Sc. has been handed in to the presiding examiner.

Free from the irresponsible entanglements of college life; free from the immediate spirit of college sports and class associations; free from the insipid monotony of lecture halls and the strain of examinations; free from much that is weary, from a little that is hopeful and from all that is theoretically ideal. Free!

Four years of college life at an end. It is indeed a moment which demands serious thought and consideration, one of the most important, perhaps, in the whole tide of the student's worldly interests.

It is the point of turning, the hour of change from indifferent and irresponsible academic conditions to responsible and productive professional life. Few of us, possibly, there are who fully appreciate the solemnity of such an occasion, our interests are so wide, varied and divided. Excitement attendant upon the packing of trunks, the hustling together of old notes, books, laboratory reports, perhaps never to be reviewed again, the buying of the railway ticket to the home-town, has necessarily obscured the issue of this important hour to many members of the class.

Others, farther removed from the influences of home and its many blessings, gravely pay our last week's room rent, count the available change and seriously consider hitting the trail to the backwoods in quest of a job. Some are happy, optimistic, others indifferent, giddy as in balmy freshmen days when we were "everything by starts and nothing long," others still are grave, pessimistic, and all so different one from another.

A few even are ambitious, while others don't care a hang. Just as in the crowds which throng life's busy thoroughfares are all sorts and conditions of men with varied outlooks upon the future, wherein keen intellects, careless ease and smug satisfaction jostle one another and pass on, so in college halls, indifference, ambition and thirsting intellects meet together, for a season, partake in common, and then are gone to meet together no more.

The history of our class on the journey through the Science course does not differ materially from that of other classes who have gone before. Many who began well in freshman days with enthusiastic desire to follow to the end, have fallen by the wayside.

The examiner's sword has been active through all the years, and the consequences have been most sorely felt. The choice at times might have been open to question, and the really deserv-

ing of every consideration sidetracked by the irregular falling of the sword, yet the issue remains, and from the original class of 325 who signed the roll in the autumn of 1908, only 187 have come through the fires of examination, inconsistency and providential interference.

Though we have been permitted to come thus far along the route, we realize that the most severe pruning has yet to be undergone—the pruning which invariably follows when theory and practice meet and compromise.

From every class that has gone before there are records of successful men. Failures there are also. Our class may prove no exception. It is but to be presumed that from every group of 187 men, some, when weighed in the balance by the demands of industry and enterprise, will be found wanting.

Men who fail, however, are not necessarily failures, and the divine charity which has a place in every student's soul forbids any syndicate to be formed of those who lack in the struggle for place in professional life.

The field of endeavor which lies outstretched along our horizon on this occasion is that of the whole round world. There is no region yet known to man where the School of Science graduate finds no scope for his best efforts.

Through all the vast prairie country of the West he may be found engaged enthusiastically in the great work of development and economic utilization of Canada's abundant natural resources.

Through the wilds of the northlands he wanders and demonstrates his engineering skill, wherever the spirit of colonization has taken root.

Nor does he confine his efforts to Canada and Canada alone. He has established himself in every continent and island, whereever industry and enterprise need development for the benefit of civilized man.

Australia has her mining and civil engineers whose names are enrolled on the School of Science calendars. South Africa, Europe, South America, even rebellious Mexico, are fields wherein old graduates of Toronto University are privileged to tarry.

This is the wide range which opens out, to Science students particularly, as they stand in silent contemplation for a short while on a bridge of their own construction between the academic and professional life. It is but natural to expect that in such a large field we shall drift far apart from one another as we plod along in the struggle for place.

The electrician will have little in common with the mining engineer.

The former enters the open doors of manufacturing houses, electric laboratories, and extensive power plants in great industrial centers, the latter travels off to the lonely wilds of the northland where the coyote howls by night and where vast treasures lie undeveloped and unknown. The civil engineer will seek the rapidly

growing towns and villages of the Western Provinces and become involved with the intricate problems of municipal life.

Others will follow the iron road to the end of the line and aid in opening up to transportation and civilization unexplored and undeveloped lands. Each and all will play some part in the great struggle of nation building, of colonization and of ideal citizenship.

Others are closely following on our heels along the trail we have come. Every year is a fourth year to some class, but no the individual it comes once only, and then the choice is made, on which depends largely success or failure in after life. Four years of college work and associations create great changes in the student and his ideas. We entered as boys, care free, from town and country, from farm and hill, from the provinces of the West, and from the islands over the sea; we pass out as men, in discretion, may we hope, as well as in years. Plans also have changed. We came teeming with all that we hoped to do; we leave, realizing how little we have done, how unprepared we are to face the great problems of industrial life, sadder but wiser men. We came with ideals, believing steadfastly in the completeness and perfection of a college course; we leave with ideals shattered by its very incompleteness and imperfection, realizing that our life's real study has only begun. It is this very shattering of ideals, consequent upon the incompleteness of four years of study, that establishes the cord of loyalty between the student and his Alma Mater, and most loyal is he who has the fullest realization of the price he has paid.

That each and all the members of our class of 1912 will choose wisely and do well to the honor and glory of the Empire, their country and their Alma Mater is the sincere and fond wish of one who has interests in common, and a human love for all mankind.

ADVANCE IN MOTOR CAR DESIGN

G. C. Parker, '10, in the "The Motor Magazine"

Considering one of the primary factors governing the manufacture of motor cars, viz., price, there is by far the greatest demand for cars of low price, that is, cars which sell for prices ranging from $1,000 to $2,000. The demand for cars of this class is not as great this year as heretofore, while that for higher priced cars is somewhat greater. The number of cars selling below $1,000 is about the same. The increase in number of high-priced cars on the market indicates confidence on the part of the motoring public that the motor car is here to stay, and will be of ever-increasing benefit. In 1911 the low-priced car was the favorite, but this year the increase is in favor of the car selling from $4,000 to $5,000.

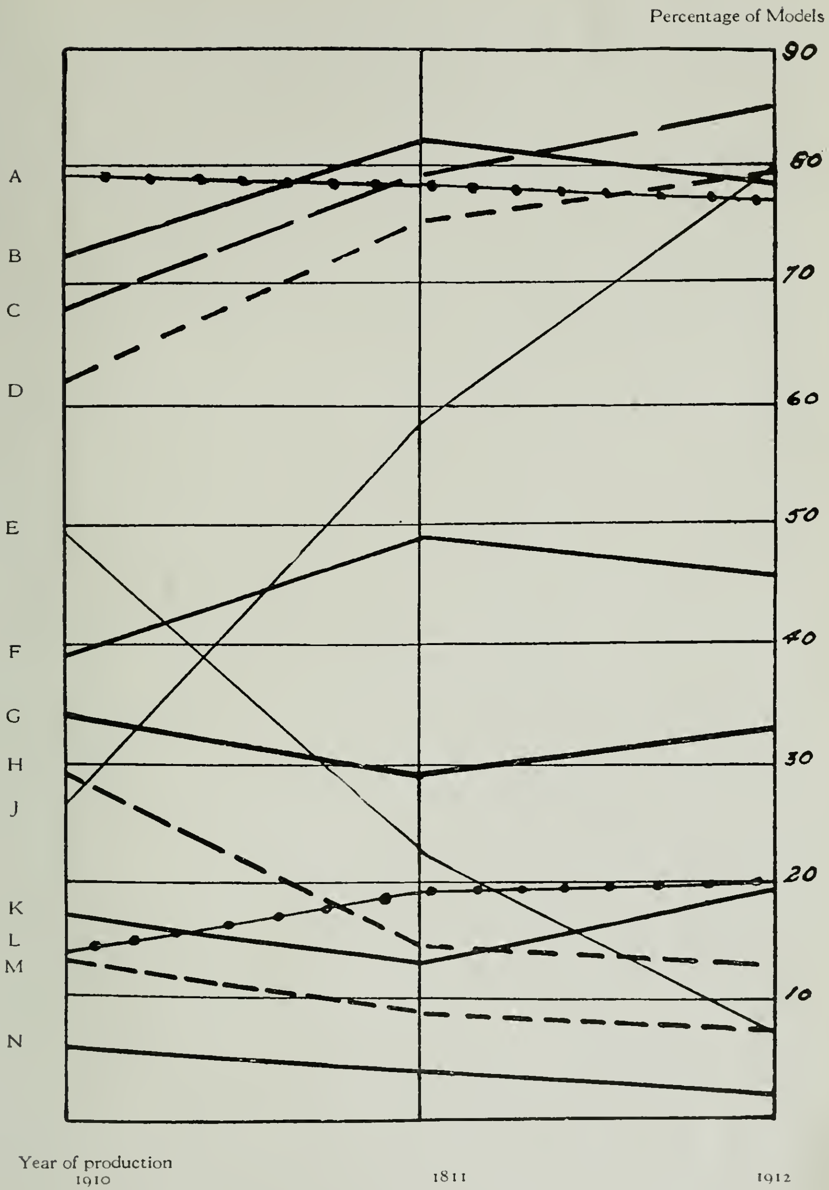
In the design of the car one of the first things to consider is the size, or wheel base. There has been, and no doubt will be, no end of discussion as to the best wheel base for general uses. There is no doubt in the minds of the designers and buyers that for touring and

country road work the long wheel base is in every way desirable. The riding qualities resulting from the use of the large wheel base are well known. For town work the short wheel base is desirable on account of the ease of turning and driving in congested traffic. Taken in a general way, it is found that there is a tendency to increase the wheel base, and that the most popular appears to be in the neighborhood of 120 inches. There has been a marked increase in the number of manufacturers making cars of this size, and a still greater increase in the cars having a greater base than 127 inches. On the other hand, there has been a decided falling off in the number of cars under the 110-inch mark. From the above, it is seen that for the time being at least, the designers have decided that a wheel base of 120 inches and greater is the best.

The question of the number of cylinders is one governed chiefly by price. The four-cylinder engine is suitable for all classes of cars, and is to be found in both the high and low priced cars. There is, however, a decided tendency on the part of manufacturers to invade the realm of the medium priced four-cylinder cars with the six cylinder. This is a case of history repeating itself. A few years ago it will be remembered that the medium, and especially the lower priced cars were almost universally fitted with two cylinder engines, and, in many cases, single cylinder engines. For a time the dividing line between the high and low priced cars was also the dividing line between the four and two cylinder engine. The manufacturers, however, soon found it possible, and perhaps necessary, on account of keen competition, to buid a four-cylinder engine to replace the two cylinder model, and to sell it for a comparatively low price. In the same manner it has come to pass that a number of cars equipped with six cylinder engines are being sold for the same price as the four cylinder cars. As will be seen from the chart, the four cylinder engine is used on 78 per cent. of the cars manufactured for the present season. There has been a decrease in the number of cars equipped with two cylinders, and a greater increase in the number of six cylinder cars.

Owing to improvements in motor design the ratio between weight and power has been increased. In other words, the pounds per horsepower has been lessened. This has been made possible by the use of materials of greater strength and lesser weight, and also by the increase in piston speed, allowing smaller moving parts, and hence giving a reduction in material. This has led to the use of engines of greater power, and, while there has been an increase in the use of engines of from 35 to 45 horse-power, the tendency is for higher powers. The day of the low powered car appears to be over, and the horse-power is steadily increasing.

A subject connected with the power of the motor is that of stroke. During the last year or so, this has been uppermost in the minds of designers, both in this country and abroad. In fact, there has been almost a complete reversal of opinion in Europe on this matter. It is not many years since the short stroke motor was in general favor. By the short stroke motor is meant the motor in



TREND OF MODERN MOTOR CAR DESIGN IN PERCENTAGE OF MODELS MANUFACTURED

A—Water Pump. B—Four cylinders. C—Dual ignition. D—Bore less than Stroke. E—Mech. oiler. F—Valves on same side. G—Valves on opposite sides. H—Bore—Stroke. J—Circular oilers. K—Six cylinders. L—Thermo syphon. M—Bore greater than Stroke. N—Two cylinders.

which the stroke is equal to or less than the bore. European engineers were loud in the praises of the short stroke, and the design was generally adopted. In America this was not so noticeable. There were a number of manufacturers who advocated the short stroke, but, on the other hand, there were many who felt that there was not sufficient justification for this.

The last year has seen a tremendous increase in the number of makers using the long stroke motor. Those who favored the "bore equal stroke" design, have increased the stroke, while those who used the longer stroke have increased it to a greater extent in their new models.

The function of the clutch is to provide a flexible method of connecting the engine to the driving shaft. On account of the inherent property of the gasoline engine, which necessitates its running at high speed before it is capable of carrying its load, some means must be provided for applying the load gradually. Obviously the most satisfactory method of doing this would be by a device that had the property of slipping. This is the principle of the clutch, and the amount of slipping depends on the nature of the surfaces in contact. In the cone clutch the slipping, and consequently the wear, takes place between two surfaces only. In practice one of these surfaces is of a soft material, confining the wear to one surface only. In the multiple disc clutch, the discs are of metal, and the wear is distributed. The number of discs may vary from four or five to forty or fifty, depending on the design. The fewer the discs the greater must be the area of surfaces, and this will result in a greater diameter for the same power. The chief objection to this is added weight in the clutch, with added diameter, which will result in greater inertia. This causes the clutch to rotate for a considerable time after release.

The band clutch, in principle, is the same as the band brake. It consists of a flexible band or two rigid sections which expand in a cylinder. The band is attached to the clutch shaft and the cylinder to the engine shaft. The method of applying is similar to that of the other types.

When changing from one speed ratio to another, especially from a lower to a higher, it is necessary for the clutch shaft to decrease in speed in order that the gears may mesh without "grinding." It is left free when released, the inertia of the clutch will cause it to revolve at a high rate of speed for some time after the release. In order to reduce the speed it has become customary to equip the car with a clutch brake. This consists of a small disc or shoe attached to the frame of the car, and normally disengaged frcm the clutch. As soon, however, as the clutch is released, some part of the revolving section comes in contact with the brake, and the rate of rotation is lowered, thus allowing the gears to be engaged.

The tendency in the design of the transmission gears is towards the introduction of another speed. The number of models with the two speed gear has practically ceased to exist, and while the three-speed gear has shown a slight falling off, the greatest increase is in

the models employing a gear set with four upward speeds. This gives two choices of speed between the low and the high, which in heavy cars is of great advantage. When used intelligently the use of the four-speed gear on the heavy car relieves the engine, especially when the car is negotiating a heavy grade or rough roads.

By far the most universal addition to the 1912 models is the self starter. These operate on four different principles, viz., mechanical, electrical, compressed air, and the explosion of gas in the cylinder. Of these the latter is the most popular, and adds but little weight to the car. Gas from the lighting tank is admitted to the cylinders through a reducing and distributing valve. The spark is then placed and the gas in one of the other cylinders will explode, turning the engine over. The compressed air system consists of a small pump connected to the engine, this charges a reservoir under pressure. To start the engine the air is admitted to the cylinders, and the engine is started as an ordinary air engine. The chief advantage of this method lies in the fact that the engine is started from rest gradually, thus imposing no undue strain on any of the parts. For the use of the electrical system there is a small electrical generator driven by the engine. This charges a storage battery, which, in turn, drives the generator as a motor when it is desired to start the engine. The generator can also be used for ignition and lighting. in connection with the storage battery. The mechanical arrangement for starting consists usually of a ratchet wheel which engages the crankshaft and is operated by a foot or hand lever. It is simply a refinement, bringing the crank to the driver's seat. Without doubt the adoption of the self starter has done more to popularize the car than any accessory that has been introduced for some time. It makes the gasolene car capable of being driven by the fair sex without placing them under the necessity of asking some passer-by to turn the engine over for them.

Taken all in all, the tendency in the design of cars for the present season has been more in the direction of general refinement and higher quality than in lower price. The manufacturers evidently believe in bringing the manufacture up to a high standard rather than down to a price. Every development tends to make the car easier to handle, more reliable and more comfortable for the occupants as well as to decrease the cost of maintenance and running repairs. There is, no doubt, still vast room for improvement. Take, for example, the case of oiling and cleaning. There is little doubt that in the cars manufactured a few years hence it will be much easier to clean the cylinders and transmission case than in the present models. During the days of the early type of car with the engine under the seat, the owner did not examine his engine any more than was absolutely necessary, on account of the necessary trouble and labor entailed by a complete examination. In the models in which the engine is under the hood, the disagreeable part of it has been done away with, and the opinion is that in future this idea will be carried out to a greater extent. No car is built to run continually

without occasionally tightening up and examination, and the easier this is to accomplish, the oftener it will be done, and this will without doubt improve the running qualities as well as lengthen the useful life of the car.

BIOGRAPHY

The eminent engineer who holds the renowned position of being foremost in the faculty calendar is Mr. J. L. Morris, 1881. He was born in Greenlaw, McNab, County of Renfrew, in 1862, was educated in the Pembroke public and high schools, and entered the School of Practical Science as a matriculant of the University of Toronto in September, 1878, from which he graduated in April, 1881. Mr. Morris spent the first summer after graduation on a Dominion Government survey in the North West Territories, in the vicinity of Fort Calgary. The following three and one-half years were spent as assistant to the engineer in charge of construction of the Eastern Division of the Canadian Pacific Railway between Mattawa and Missinabie. From June, 1885, until the close of 1886, he was on maintenance of way for the Canadian Pacific Railway between Montreal and Port Arthur. From that time up to the present, Mr. Morris has been in private practice in Pembroke, Ontario, as civil engineer, architect, and land surveyor. The firm has been known as Morris & Moore since January of 1909.

Mr. J. L. Morris, 1881

In June, 1885, Mr. Morris prepared a thesis with accompanying plans on "Masonry and Temporary Works" for the degree of C.E., Toronto University. He was granted the land surveyor's certificate for the province of Ontario in September of that year. He became an associate member of the Canadian Society of Civil Engineers in February, 1887, and a member in January, 1904. He is also a member of the Ontario Association of Architects since 1901.

Among the many engineering enterprises upon which he has been engaged and pertaining particularly to the design and construction of permanent bridges, since his taking up private practice in Pembroke, may be cited the following: a stone arch bridge in Pembroke costing $20,000., and another over the Bonnechere River at Eganville costing $16,000.; a steel highway bridge of five spans over the Madawaska River at Claybank costirg $30,000.; a single steel highway bridge over the Bonnechere River at Horton costing $9,000.; another steel highway bridge, a single span over the Indian River,

Pembroke, costing $7,500., and a three-span steel highway bridge over the Bonnechere River at Renfrew costing $8,000.

Mr. Morris was manager of the W. J. Poupore Co., of Montreal, on the construction of the Chateauguay and Northern Railway from Montreal to Joliette, and the sub-structure of the Bout de l'Ile bridge over the Ottawa River in 1905, the cost of the sub-structure being $150,000.

He designed and superintended the construction of a sewer system for the town of Pembroke in 1899. This included an outlet 2,400 feet in length under the bed of the Ottawa River to deep water. He likewise designed for the town of Prescott a sewer system, septic tank and outlet, in the year 1910. He designed and superintended the construction also of a power plant and transmission line from Black River to Pembroke, a distance of fourteen miles, 1908, the cost amounting to $150,000.

Mr. Morris has been senior partner in the firm of Morris, Mackie & Co., on the construction of a section of the Transcontinental railway including the Armstrong yard and round house, since 1910.

Among engineers who find themselves so completely engaged in their profession, it is but seldom that a sacrifice of time is made for preparing for the technical press, articles based upon the work on which they are engaged. We find, however, that Mr. Morris has not ignored this important feature of every engineering experience. In 1888 he compiled a paper entitled "Masonry Foundations" for the Land Surveyors' Association, to be followed in 1890 by another entitled "Compass Lines," for the same Society. In 1906 he presented a paper to the Canadian Society of Civil Engineers upon the Bout de L'ile bridge.

During the thirty-one years that have elapsed since Mr. Morris graduated from the School of Practical Science he has engaged in various branches of engineering, and with like success in all. Apart from the credit due to him for his ability as an engineer, this success shows that even in the early days of this institution the value of broad general training was recognized and well taken care of by our worthy Dean.

BRANCHES OF THE ENGINEERING ALUMNI

The various branches of the University of Toronto Engineering Alumni Association, with their presidents and secretary-treasurers, are as follows:—

Montreal Branch—President, G. H. Duggan, '83; secretary-treasurer, H. W. Fairlie, '10, 657 Dorchester St. West, Montreal, P.Q.

Pacific Coast Branch—President, E. B. Hermon, '86; secretary-treasurer, N. R. Robertson, '06, 202 Winch Bldg., Vancouver, B.C.

Pittsburg Branch—President, Gardiner Alison, '03; secretary-treasurer, M. L. Miller, '03, 206 Suburban Ave., Pittsburg, Pa.

Toronto Branch—President, J. C. Armer, '06; secretary-treasurer, H. Irwin, '09, Engineering Building, University of Toronto, Toronto, Ont.

Timiskaming Branch—President, E. V. Neelands, '00; secretary-treasurer. H. W. Sutcliffe, '07, New Liskeard, Ont.

The interests of School men residing in New York City are ably looked after by the University of Toronto Club of New York, of which Dr. Charles Graef is president, and T. Kennard Thomson, '86, 30 Church St., New York, is secretary-treasurer.

There is urgent need of branches being formed immediately in Ottawa, Winnipeg, Regina, Calgary and Edmonton. In each of these centres between 25 and 50 graduates are located, while the men in the immediate vicinity would slightly increase these numbers, forming in each instance an ideal working body in which matters pertaining to the Faculty of Applied Science and its graduates could be ably discussed. We hope to hear of these branches being formed.

OBITUARY

A shade of gloom was cast over the University upon the arrival of the news of the death of Mrs. Dushman, wife of S. Dushman, Ph.D., of the Department of Electrochemistry. Mr. Dushman had but recently taken up his location at Schenectady, N.Y., where he was to have engaged in original research during the summer. In less than two weeks after their departure from this city, however, Mrs. Dushman was seized with appendicitis and lived only a few days. The remains were brought back to Toronto for burial. Dr. Dushman has the sincerest sympathy of his many friends and acquaintances in the Faculty of Applied Science and throughout the University.

Equally sad is the misfortune which befell Mr. O. B. McCuaig, a graduate of '07. Mr. McCuaig was engaged as general superintendent of the Winatchee Light & Power Co., of Winatchee, Washington, since resigning his position as chief engineer on telephone construction on the T. & N. O. Railway. Mr. McCuaig had the misfortune to lose his bride of a year who died suddenly in Washington a few weeks ago. To him also we extend heartfelt sympathy.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published every month in the year by the University of Toronto Engineering Society

SUBSCRIPTION RATES

Per year, in advance	$2.00
Single copies	20

Advertising rates on application

Address all communications:

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

EDITORIAL

BIOGRAPHIES OF GRADUATES

We strive to interest our graduate, and find that in the rush of summer business, while he keeps the venturous public constantly picking steps over freshly laid side walks, gaping trenches, and road beds in the making, his desire for reading does not denote the task to be easy. His time for reading confines itself to narrow scope, and it must be of real interest to command attention. In a new department entitled "School Men," beginning with this issue and to appear continuously, we hope to supply something of interest to every one who receives the Journal. Its information, furthermore, will be thoroughly reliable. Its pages will be perused by students to whom they will monthly disclose the vast breadth of engineering fields and the adaptability of graduates of this institution to them. Class mates need not be prompted to read the biographics of their one-time fellow students and constant associates in the profession. In short, every one will, it is

expected, take kindly to the biographies of "School" men; and to render the department useful by its completeness APPLIED SCIENCE solicits a biography similar to the one published in this issue, from all graduates. As many will be published as space given to the department will permit.

This is not merely an incentive to collect material for publication. We want all the information that can be had regarding the professional standing of graduates of this Faculty. The material with which the graduate supplies us is being put to another use, that of establishing for the engineering alumni a record of all its members. More is said of this in another column.

TO GRADUATES

The circular letter which every graduate received a few days ago will be given his immediate consideration, it is to be expected. There is very incomplete information at hand about the professional work our men have been doing since graduation. The University of Toronto Engineering Alumni Association should have in some convenient form complete statistics regarding the lines of work the Alumni follow. The criterion of the value of the training given in any University must be sought for, and will be found, in its graduates. The Faculty of Applied Science has been most instrumental in furnishing the engineers who have built up the profession in Canada and elsewhere. Building up a profession in any country signifies building up the country.

We sometimes hear it said that the Faculty of Applied Science does not receive its due at the hands of the Board of Governors at the University. Whether this is or is not the case is a subject of grave importance to every graduate. We are all indebted to the School for advantages and favors and for the devotion of the men within its walls to the advancement of its good work, though the recompense does not compare with that of positions of similar responsibility and importance in other walks of life. There is this and other questions of equal importance to be answered by the graduates of the School. The significance of their answer is indefinable until the knowledge of the strength of School men in the profession of engineering is broadcast in general and brought home in particular to University authorities.

The graduate form which is enclosed in the circular letter will do a great deal towards assisting in compiling useful data concerning the output of the School and its place among other faculties of the University of Toronto. Indeed, a fairly complete return of these circulars is absolutely necessary. Again, the various branches of the engineering alumni—namely, those in Montreal, Vancouver, Temiskaming, New York and Pittsburg, are most interested in the progress of the School. Those who are so situated that they can affiliate themselves with any of these branches should do so as early as possible as important questions will undoubtedly be dealt with. Where a number of School men reside in other towns, similar branches

should be organized and maintained. It is in this way that we can best unite our efforts in the furtherance of School affairs.

SCHOLARSHIPS

The circular letter mentioned in another paragraph contains information concerning what has been done by the Toronto branch of the Engineering Alumni Association in the establishment of research scholarships in the Faculty of Applied Science. A number of applications have been received and many of them considered. Before awards are made in July, however, an opportunity is given to every graduate of the institution to apply, if he so desires, for one of these scholarships, and to this end an application blank was enclosed with the letter.

As stated, upwards of $1,000 has already been subscribed for this movement. This amount is the result of a number of requests for support that were made promiscuously by members of the executive. Other subscriptions which came unsolicited, and numerous enquiries regarding the enterprise have led to this call for the co-operation of all School men. The subscription form which was mailed in conjunction with the circular letter may be filled out and returned in the accompanying envelope, or at any other time. The application for scholarship, on the other hand, should be mailed before July. The graduate form, however, should receive earliest attention, be filled out as completely as possible, and returned in the enclosed envelope. We trust that this request, which is in the interests of all our readers, has received, or will receive, early attention.

MONTREAL GRADUATES' DINNER

The second dinner for the season of the Montreal branch of the Engineering Alumni was held on May 12th, the president, Mr. G. H. Duggan, being master of ceremonies. Unfortunately, many of the senior graduates were unable to be present, being absent from the city, and only about thirty men were in attendance. Owing to the busy season this was almost to be expected, but the enthusiasm which presided over the meeting is assuring that the Montreal dinner is a well established function, and that next year's attendance will be greatly increased. Two features of the evening that were most encouraging were: the presence of a number of "School" men who had not previously associated with the branch, many of them being unknown to quite a number of the younger graduates. The other feature was the manner in which the graduates who were visiting in the city accepted and enjoyed the hospitality of the meeting. The desire of the Montreal Club is to make these meetings the stamping ground of graduates in the city, and the officers of the association are doing a great deal to round up all "School" men within reach.

The "social and musical" evening that had been promised by invitation was not finally achieved until after some argument

with "mine host," but the calisthenics of E. A. Thompson, '09, to the music of Madden were well worth the effort. "Babe" Reynolds, although compelled to leave early, entirely without incrimination, was much appreciated in a couple of his songs. His ability will be remembered at similar functions in future, at which no excuse of previous engagements will be tolerated.

Space does not permit a detailed account of all the evening's good entertainment. It only remains to be stated that there is a standing invitation for every "School" man in Montreal or vicinity to come and enjoy for himself the meetings of the graduates.

THE ALUMNI IN NORTHERN ONTARIO

The annual meeting of the Temiskaming branch of the Engineering Alumni Association was held in the Board Room of the Mine Managers' Association at Cobalt on April 30th. Major R. W. Leonard of the Board of Governors of the University of Toronto, was elected honorary president, while Mr. E. V. Neelands B.A.Sc., '00, manager Hargreaves Mine, Cobalt, is president for the coming year. The secretary-treasurer is Mr. H. W. Sutcliffe O.L.S., '07, New Liskeard, Ont.

Representing Cobalt, Messrs. C. G. Williams, B.A.Sc., '03, manager of the Nova Scotia mines; B. Neilly, B.A.Sc., '07, manager of the John Black mines, and A. D. Campbell, B.A.Sc., '10, of the O'Brien mine, were elected to the council. Representing Porcupine, Messrs. S. Thorne, B.A.Sc., '00, manager the Preston East Dome Mines, and F. J. Bedford, '08, are councillors. Haileybury and Liskeard are represented by G. T. Somers, B.A.Sc., '07; the T. & N. O. Engineers by R. Keys, '08, North Bay; Elk Lake and Gowganda by George Johnston, '00, and the Transcontinental Railway by Ross Harstone, '09, of Cochrane.

The roll of the Temiskaming branch includes the names of over 50 graduate members together with a number of undergraduates. Arrangements are already under way for the annual dinner next fall. It will undoubtedly be the largest reunion ever held by the Association.

EXPLORATION PARTY FOR THE NORTH

Mr. J. B. Tyrell, M.E., in charge of a party of engineers on exploration work for the Provincial Government, will leave in a few days for Winnipeg. From that city they will proceed north to Fort Nelson. Professor L. B. Stewart, O.L.S., D.T.S., professor of surveying and geodesy; W. B. McPherson, B.A.Sc., and R. B. Stewart, M.A., B.A.Sc., will accompany him. The party will be away until October or November and will be engaged on the survey of the mouth of the Hayes River and of Ontario's newly acquired territory on Hudson's Bay.

REGINA ENGINEERING SOCIETY

The Engineering Society of Regina, with members and guests numbering 65, held a very successful dinner on the 2nd instant. The president, A. J. McPherson, 93, acted as toastmaster. The dinner was largely attended by School men in the city. Mr. McPherson gave an exceptionally interesting address entitled "The Future of the Engineering Profession in the West." He emphasized the growing importance of engineering skill and various adaptations to the industries. In this regard he mentioned the wide field the engineering profession has in the development of Canada's coal, forest and water power resources, apart from the solving of the many engineering problems pertaining to this development. Mr. R. E. W. Hagarty, '07, replied to the toast "Canadian Industries" in a most able manner, pointing out Saskatchewan's peculiarly advantageous possibilities for industrial development. Mr. Thornton, in proposing the toast, observed how dependently Canada's world-wide industrial reputation rests upon the engineering profession. Mr. Martin, who proposed the toast "Our Railway Systems," spoke of the status of the engineer in the forefront of every problem of transportation, of water power, of water supply, etc. The alluring opportunities for engineers in Saskatchewan were among the foremost in the Dominion because of the great and as yet barely developed resources, and the engineering problems they have presented.

In proposing the toast to the "Engineering Profession," Mr. O. W. Smith spoke of the work of the engineer as being a service to humanity in the broadest sense of the term. The engineer is one of the important pioneers in all countries and the hardships and toil which he is so often compelled to face call for peculiarly strong qualities of character.

The reply was given by J. Darlington Whitmore, who spoke of the engineer as the painstaking servant of the community. The engineer serves the community by attending to the smallest details of household convenience and to the greatest works of transportation, not stopping short of laying his wires across the ocean bed.

At a meeting of the Albany Society of Civil Engineers, of which Russel S. Greenman is president, Mr. T. Kennard Thomson, '86, delivered an illustrated address on "Caisson Foundations." The meeting was held on April 22nd.

EXAMINATION RESULTS

New B.A.Sc. Men

Following is a list in alphabetical order of the successful men in the examination for the degree of Bachelor of Applied Science, University of Toronto.

Honors

J. Aitken, L. A. Badgley, T. W. Brachinreid, W. H. D. Brouse, W. C. Cale, W. W. Chadwick, R. B. Chandler, D. B. Cole, J. H. Craig, C. H. Cunningham, J. M. Duncan, J. A. Elliott, R. J. Fuller, F. G. Hickling, H. Hyatt, J. T. King, M. Kirkwood, J. Lanning, T. A. McElhanney, W. G. McIntosh, R. A. McLellan, R. V. Macaulay R. E. MacBeth, A. D. MacDonald, A. E. MacGregor, E. G. MacKay, H. H. Madill, J. E. Malone, J. H. Parkin, F. M. Pratt, J. E. Ratz, L. J. Rogers, F. V. Seibert, C. P. Sills, M. L. Smith, W. C. Smith, A. E. Stewart, R. A. Story, P. G. Welford, E. R. Williams, W. H. Wilson, W. J. T. Wright, A. Young.

Pass

L. B. Allan, E. G. Archer, W. J. Baird, T. H. Bartley, J. H. Billings, J. R. Bissett, W. J. Boulton, H. O. Brown, G. H. Burnham, P. G. Cherry, E. F. Chesnut, H. J. Clark, A. S. Cook, W. M. Crothers, F. K. D'Altong, W. B. Davis, F. C. DeGuerre, W. B. Dunbar, C. H. Eckert, C. F. Elliott, G. R. Elliott, W. J. Evans, K. A. Farrell S. E. Flook, E. L. Frankel, E. E. Freeland, J. R. Freeman, J. M. Gibson, J. L. Gooderham, H. Goodridge, E. B. Graham, E. A. Greene, G. M. Hamilton, M. B. Heebner, H. R. Hill, O. H. Hoover, A. J. Huff, R. H. Jarvis, P. T. Kirwan, M. Lieberman, A. L. Long, A. W. P. Lowrie, J. B. McAndrew, H. J. McEwen, W. G. McGhie, D. A. McKenzie, A. J. McLaren, W. B. McPherson, A. A. McQueen, W. M. McAndrew, F. M. Macdonald, J. G. MacLaurin, G. G. MacLennan, A. W. R. Maisonville, N. Marr, J. C. Martin, C. H. Meader, L. G. Mills, J. A. Murphy, J. C. Nash, E. H. Niebel, C. K. Nixon, E. S. Noble, R. K. Northy, W. A. O'Flynn, J. A. Orr, J. S. Parker, J. McD. Patton, W. J. Perrin, B. W. Bick, L. J. Quinlan, F. N. Read, W. A. Richardson, W. E. Robinson, D. Ross, O. W. Ross, F. G. Rutley, F. R. Scandrett, Miss H. E. Scott, J. W. Scott, N. D. Seaton, M. R. Shaw, W. C. Shaw, R. G. Sneath, R. J. Spry, G. E. Squire, W. S. Steele, R. Stewart, R. Taylor, J. B. Temple, E. A. Ternan, R. D. Torrance, W. G. Tough, J. H. C. Waite, W. D. Walcott, R. M. Walker, G. L. Wallace, A. Wardell, F. E. Watson, B. W. Waugh, A. G. Wheeler, J. L. Whiteside, G. H. Whilkes, W. G. Worden, W. H. Wylie, S. Young.

Supplementals

The following men must take supplemental examinations in subjects indicated before they are eligible for the degree:—W. O. Boswell (electricity), E. O. Ewing (str. of materials), R. E. Green (electricity), A. J. McFadyen (3rd year astronomy and geodosy), F. H. McKenzie (str. of materials), M. H. Murphy (hydraulics), V. J. O'Donnel (electricity), H. Pullan (thesis), E. V. Reid (thesis), P. Sheard (thesis), F. H. Wrong (hydraulics).

The results for other years are given alphabetically below. A subject in parenthesis denotes that the man whose name it follows must pass a supplemental before clear standing is obtained.

THIRD YEAR

Civil Engineering

Honors

W. B. Beatty, B. S. Black, G. M. Cook, A. G. Gray, E. R. Gray, A. W. Hayman, R. L. Hearn, H. J. Heinonen, O. Holden, H. R. MacKenzie, K. F. Mickleborough, W. C. Murdie, J. E. Perron, J. E. Ritchie, L. Sewell, W. G. Ure, D. H. Weir.

Pass

C. R. Avery, F. W. Beatty (hydraulics), D. Blain, O. L. Cameron (theory of const. hydraulics), L. L. Campbell, G. M. Carrie (th. of const. hydraulics), W. G. Clark (photography), J. A. Coombs (method of least sqs. astr. and geod.), A. J. Dates, F. R. Fiddes (th. of const. ltd. cos.), D. H. Fleming (ast. and geod.), E. S. Fowlds J. S. Galbraith, A. M. German (calculus. th. of const.), H. M. Goodman (th. of const.), J. R. Hamilton (th. of const. photography), H. A. Hawley, J. T. Howard (Eng. chem.), E. T. Ireson, G. R. Johnson (st. of mat'ls. lab., Eng. chem.—, R. L. Junkin (meth. of l'st sqs.), J. S. Laing, N. Lawless (ast. and geod., Eng. chem.), T. V. McCarthy, W. L. McFaul, R. J. McKenzie (th. of const.), A. R. MacPherson (ast. and geod.), W. H. MacTavish, N. C. Millman, T. R. Moore (asst. and geod.), F. J. Mulqueen (meth. of l'st sqs.), N. F. Parkinson (photography), J. J. Phillips (th. of const.), H. C. Quail (ast. and geod.), J. M. Riddell, C. S. Robertson (th. of const.), W. A. Spellman (Ltd. cos.), D. Sutherland (th. of const. photography), R. Tasker (ast. and geod., surveying), J. M. Thompson, C. F. vonGunten, W. S. Winters (French), R. F. B. Wood (ast. and geod., calculus).

Mining Engineering

Honors

R. E. Binns, R. W. Diamond, K. L. Newton, D. G. Sinclair, W. K. Thompson.

Pass

C. A. Bell, T. R. Buchanan, W. B. Caldwell (petrography mining), R. T. Carlyle, H. Clark (mining), W. T. Curtis (th. of const. hydraulics), W. H. Garnham, A. C. McDougall (anal. chem., mining), D. A. S. Mutch, R. M. Trow (met. of gold).

Mechanical Engineering

Honors

A, S. Anderson, F. R. Simms.

Pass

B. H. A. Burrows (elec. alt. current), R. M. Carmichael, B. D. Clegg, H. D. Davidson (th. of const. hydraulics, F. F. Foote, A. J.

Gray, R. A. Henry (alt. current), K. E. Shaw, R. E. Watts (th. of const., elec.), C. A. Webster.

Architecture

Honors

L. C. M. Baldwin, B. R. Coon, H. D. Livingstone, R. S. McConnell.

Pass

B. Brown (calculus photography), R. W. Soper, H. Webster (th. of const.).

Analytical and Applied Chemistry

Honors

A. R. Bonham, L. W. Doncaster.

Pass

J. C. Huether, C. J. Otto, (heat lab.).

Chemical Engineering

Honors

G. E. Clarkson.

Pass

K. S. McLaughlin, P. J. Relyea.

Electrical Engineering

Honors

R. J. Allen, L. R. Brereton, W. B. Buchanan, T. A. Hill, G. J. Mickler, E. G. Ratz, C. C. Rous, M. C. Sharp, J. M. Strathy, D. J. Thomson, J. A. H. Wigle.

Pass

R. S. Bell (elec. design), E. R. Bonter, J. H. Coleman, E. L. Deitch, W. G. Duncan, J. P. Hadcock, H. C. Harris, T. F. Howlett (electro-chem.), S. S. Kelly, A. E. Kerr, C. E. Kilmer (hydraulics, alt. current), A. Leslie, L. B. Lytle (elec. design, photography), H. A. MacKenzie (thermo. elec.), J. W. Peart, C. H. Russell (alt. cur., electro-chem.), A. A. Scarlett, T. E. Torrance (thermo., photography), H. E. Whitely, A. J. Wright, R. B. Young (alt. cur.).

SECOND YEAR

Civil Engineering

Honors

F. C. Adsett, J. L. Alton, E. L. Bedard, H. J. Bedard, M. deG. Boyd, D. H. Campbell, J. J. Campbell, W. Cuthbertson, R. D. Davidson, F. W. Douglas, H. E. Eyers, O. M. Falls, J. W. H. Ford, J. L. Foreman, J. J. Hanna, L. T. Hayman, B. B. Hogarth, H. O.

Leach, R. E. Lindsay, C. T. Lount, D. McCaw, R. C. McDonald, H. E. Macpherson, H. N. Macpherson, F. C. Nechin, J. R. Montague, E. P. Muntz, C. Noecker, A. H. Parker, R. G. Patterson, H. L. Sheppard, J. B. Skaith, C. N. Temes, F. T. Van Dyke.

Pass

J. T. Belcher, S. G. Bennett (surveying, hydrostatics), P. V. Binns, J. M. Blythe, J. H. W. Bower, R. M. Christie, W. W. Code (Eng. chem.), C. P. Cotton, (calculus, Eng. chem.), J. W. Crashely (spher, trig., org. chem.), G. F. Dalton, R. F. Davidson (org. chem., Eng. chem.), J. A. Elliott, (trig., calculus), G. O. Fleming (hydrostatics), C. H. R. Fuller, R. W. Gouinlock (astronomy, Eng. Chem.), J. H. Hawes (hydrostatics), S. A. Hustwitt, R. P. Johnson (spher. trig.), J. Kay, N. G. Keefer (Eng. chem., mineralogy), J. A. Knight, C. A. Macdonald (sur., min.), J. A. P. Marshall, W. G. Millar, A. S. Millar (cal., hydrostatics), J. S. Mitchell, E. B. O'Connor (cal. min.), W. M. Omand (dyn., optics), J. A. Owens, C. W. Pennington (calculus), C. V. Perry, P. H. Raney (min)., R. H. Rice (spher. trig., sur.), H. M. Rowe (chem. lab.), F. S. Rutherford (dynamics), N. E. Sheppard (hydrostatics), S. Shupe (calculus, sur.), C. E. Sinclair (str. of materials, Eng. chem.), R. B. Sinclair (min. lab.), H. M. Smith (min. lab., org. chem.), N. L. Somers, R. A. Steven, I. R. Strome (min.), G. E. Treloar, H. O. Waddell, H. W. Wagner, H. D. M. Wallace, P. L. Whitely (min., banking and finance), H. P. Wilson (Eng. chem.), G. A. Wood.

Mining Engineering

Honors

W. A. Macdonald, J. G. Shepley, B. N. Simpson.

Pass

F. C. Andrews (inorg. chem., Eng. chem.), E. P. Cameron (min., geology), J. M. Carter, W. A. Delahaye, S. D. Ellis (chem. lab. quant.), J. S. Fleming, J. R. Gill, D. S. Halford (min. lab., surveying), W. Hutchings (min., geol.) S. A. Lang (calculus), H. J. MacKenzie (calculus), W. D. Powell (mineralogy), J. Ross (min.—, lab., optics), C. M. Scarborough (trig.), G. M. Smyth (inorg. chem.), G. B. Taylor, J. S. Taylor (inorg. chem.), J. A. Tilston (trig., inorg. chem.), R. W. Young (calculus, Eng. chem.).

Mechanical Engineering

Honors

H. H. Brown, E. D. W. Courtice, G. H. Hally, H. S. Kerby J. G. Scott.

Pass

H. M. Campbell, W. H. Hall (cal. Eng. chem.), B. MacKendrick (steam engines, optics), F. H. Mason (steam engines, banking-finance), H. W. Maxwell, D. L. Munro (Eng. chem.), A. K. Purdy (cal., steam engines), E. H. Tennent (calculus), M. F. Verity (optics).

Architecture

Honors

W. C. Skinner, A. C. Wilson.

Pass

H. Heaton, E. E. H. Hugli (hydrostatics, hist. of arch.), J. M. Roberston (hydrostatics).

Analytical and Applied Chemistry

Honors

J. G. G. Frost.

Pass

J. E. Clark, A. J. Holden, O. G. Lye, W. E. Phillips.

Chemical Engineering

Honors

C. N. Candee.

Pass

W. E. Milligan, D. Morrison, A. W. Sime, E. A. Twidale, A. E. Wigle.

Electrical Engineering

Honors

H. M. Black, A. W. Crawford, H. F. Elliott, H. J. Franklin, A. S. Jannati, C. W. Latimer, W. E. Longworthy, A. M. Mackenzie, R. G. Mathews, P. H. Mills, L. O'Donnell, G. O. Philp, R. O. Standing, E. C. R. Stoneman, G. C. Story.

Pass

C. E. Armer, B. W. Bemrose (calculus, steam engines), A. L. Birrell (first year dynamics, hydrostatics), W. D. Brown, H. A. Campbell (calculus), H. C. Edwards (calculus), D. T. Flannery, E. I. Gill (electricity,) C. I. Grierson (Eng. chem), G. E. Griffiths (first year dynamics, trig.), R. C. James, C. M. Jones (calculus, electricity), J. I. Kammin (Eng. chem.), J. A. Kerr (chem. lab.), G. E. Kewin (steam engines), J. S. McIntyre (chem. lab.), D. L. McLaren, J. A. Marshall (org. chem.). E. T. Martin (steam engines), J. A. Nichols (calculus, theory of mech.), C. L. Nicholson (calculus), J. D. Peart, A. S. Robertson, H. D. Rothwell (first year French, calculus), W. E. Russell (str. of mat'ls, elec.), W. M. Ryan (accounts, calculus), A. G. Scott (des. geom.), F. M. Servos, W. S. Tull.

FIRST YEAR

Civil Engineering

Honors

L. Adlard, F. D. Austin, E. D. Brouse, W. G. Brown, L. R. Brown, F. M. Buchanan, G. A. Cockburn, R. M. Cockburn, N. H.

Daniel, W. L. Dickson, C. A. Doherty, A. C. Evans, W. G. French, R. D. Galbraith, E. R. Grange, J. E. Hanlon, C. E. Hogarth, C. W. H. Jackson, G. W. F. Johnson, R. E. Laidlaw, R. G. Lye, K. D. McDonald, D. F. McGugan, A. R. Mendizabel, G. Mitchell, J. T. Mogan, H. R. Nicklin, H. S. Nicklin, C. F. Porter, J. E. Porter, W. E. Brayley, A. A. Richardson, E. H. Scott, R. G. Scott, J. H. Shaw, J. A. Thom, J. H. Wallis, F. Weir, J. N. Williams, J. C. Wilson, H. A. Wood, J. A. Trebilcock.

Pass

A. C. Anderson (dynamics), F. A. Bartlet (trig.), H. R. Browne (trig., elem. chem.), L. Chavignaud (accounts), J. D. Cook (dyn.), A. B. Crealock, E. V. Deverall, W. L. Dobbin (elem. chem.), G. A. Downey, H. S. Falconer (dyn.), W. Fraser, L. F. Gaboury (trig., dyn.), G. A. Gooderham (trig.), G. S. Gray, M. Gurofsky (accounts), C. E. Hastings (dynamics, elem. chem.), C. Hayward (algebra, trig.), J. W. Hermon, (dyn., accounts), R. R. Hewson (dyn.), W. E. Irwin, E. H. Jupp (algebra), A. M. Little (French), W. E. Lockhart, E. V. McKague, J. McLaughlin (dyn., elem. chem.), G. D. Maxwell, B. M. Morris, (dyn. elem. chem.), M. A. Neilson (trig.), P. L. Pearce (dyn.), N. L. Powell, G. Rankin (dyn.), W. B. Redman, W. B. Scott (accounts), J. S. Sheehy, J. F. L. Simmons (dyn. accounts), R. M. Spiers (trig. dyn,.) F. S. Storms (elem. chem., accounts,) G. S. Stratford (dyn., accounts), J. E. Tremayne (dyn., accounts), J. A. Vance, L. P. Vezina (algebra, elem., chem.), C. H. Wheelock, L. Withrow (trig., dyn.),

Mining Engineering

Honors

F. M. D. Carmichael, E. R. Emmerson, J. S. Gitson, M. S. Hasa, W. T. Hall, L. T. Higgins, W. R. McCaffrey, I. M. Macdonell, S. Peterson, H. Stewart, J. B. Stitt, J. E. C. Stroud, W. S. Wilcock.

Pass

W. Allan (sur., accounts), M. R. Arthur, C. K. Macpherson (dyn.), L. F. Simpson (anal. geom.), B. C. Tomlinson (accounts).

Mechancial Engineering

Honors

R. H. Lloyd, W. R. McGhie, J. C. Newcombe, A. N. Payne.

Pass

J. N. Cunningham (algebra, trig.), J. L. Delisle (trig., elem. chem.), J. Gray, W. S. Kidd, R. B. McBride, H. M. Peck, F. G. Reid, J. D. Relyea (trig., elec. and mag.), A. H. Smyth, H. C. Taylor (trig., dyn.), D. B. Webster (dyn.).

Architecture

Honors

K. C. Burness, M. Dennison, T. S. Graham, A. Morris, J. T. Rose.

Pass

H. J. Burden, R. W. Catto (algebra, accts.), J. J. Davidson (accts. bldg. meas'ts), G. R. Edwards (trig., elem. chem.), N. H Korn (elem. chem., French), R. Tyrwhitt (trig., accts.), W. S. Wilson.

Analytical and Applied Chemistry

Honors

W. P. Brodie, S. Feather, F. F. Hicks, W. Uffelman.

Pass

N. B. Brown (elec. and mag.), H. Cole, G. G. Macdonald (trig., accts.), W. D. Morris, W. H. Stark (prac. min.), L. T. Watson (trig.).

Chemical Engineering

Honors

L. G. Glass, A. A. Swinnerton.

Pass

J. A. Breithaupt (accts.), H. Ramsay (trig.), A. M. Thomas.

Electrical Engineering

Honors

P. Bennett, C. J. Davey, J. Dibblee, R. V. Elliott, E. W. Ellis, W. J. Fulton, D. German, W. H. R. Gould, T. P. Ireland, A. G. Ironside, H. C. Karn, G. W. Larwence, C. R. McCort, E. W. Savage, W. G. Shier, C. N. Simpson, C. A. Smith, W. A. Steel, A. N. Suhler, C. C. Rance, J. Richmond, J. D. Stone, A. L. Ward, F. M. Ward.

Pass

W. V. Ball, T. R. Banbury, V. A. Beacock (elem. chem.), W. H. Bonus (dyn., elec. and mag.), H. C. Budd, (trig.), J. M. Carswell (elem. chem.), F. H. Chandler, W. W. Code (dyn.), G. P. Davidson, W. A. Dean (algebra, dyn.), C. W. Dobbin (trig.), A. Fleming (trig. dyn.), L. W. Harrow, S. J. Hubbert (algebra), J. A. Kennedy, J. E. McLarty (trig., French), A. H. Macfarland, T. R. Manning, W. H. Metz, W. R. Meyer (elem. chem.), C. W. Mollard, E. M. Monteith (elem. chem. French), W. B. Patterson (algebra, dyn.), W. F. P. Purdy (elec., and mag.), N. F. Seymour (elem. chem.), J. L. Skinner (trig., elec. and mag.), A. G. Smith (elec. and mag.), A. N. Taylor (algebra, trig.), A. S. Robertson, W. F. Rosar (dyn., elec., and mag.), A. C. Ross (algebra), S. M. Wegdwood, A. E. Widdicombe, F. C. Wilson (dyn., elem. chem.).

SUPPLEMENTAL EXAMINATIONS

Passed

J. H. W. Bower (trig.), F. J. Cannon (elem. chem.), G. F Dalton (trig.), J. A. Elliott (algebra), J. H. Hawes (trig.), W. G. Millar (trig.), J. A. Owens (elem. chem.), F. S. Rutherford (trig.), N. E. Sheppard (trig.), R. A. Steven (trig.), P. L. Stevens (trig.), I. R. Strome (elem. chem.), P. L. Whiteley (trig.), E. O. Wood (chem. elem.), B. Walton (anal. geom.), J. R. McIntosh (trig. surveying), H. R. Hopkins (anal. geom., trig.), W. E. Longworth, (trig.), J. S. McIntyre (dynamics, trig.), E. T. Martin (accts., algebra), J. A. Nichols (algebra, trig.), H. D. Rothwell (trig.), G. R. Mansell (algebra), J. S. Taylor (trig.), F. H. Mason (elec. and mag., dynamics), E. M. Abandana (surveying), O. L. Cameron (calculus, French), L. L. Campbell (hydrostatics), G. M. Carrie (calculus), J. C. Christner (astronomy), J. A. Coombs (optical lab.), A. M. German (French), J. R. Hamilton (calculus), J. T. Howard (prac. min.), G. R. Johnson (astronomy, optical lab.), R. L. Junkin (surveying), J. S. Laing (calculus), R. J. McKenzie (calculus), A. R. MacPherson (calculus), T. R. Moore (prac. min.), J. J. Phillips (calculus, banking and finance), C. S. Robertson (prac. chem.), R. F. B. Wood (French), G. L. Berkeley (prac. ast. and geod.), A. W. Pearson (elec.), L. Eadie (elec. retaining walls), K. E. Shaw (hydrostatics), J. H. Curzon (econ. geol.), J. H. Coleman (calculus),J. P. Headcock (calculus, th. of mechanicism), C. E. Kilmer (prac. chem.), T. R. Buchanan (calculus, mineralogy), H. Clark (optical lab.), A. C. McDougall (geology), A. R. Bonham (min. bal.), J. C. Huether (phys. chem., optics), L. A. Badgley (surveying), R. G. Sneath (asst. and geol.), W. G. Worden (sur., hydraulics), M. B. Heebner (anal. chem., thermo.), A. J. McLaren (min. lab.) E. A. McPherson (elec.), W. H. Wylie (th. of const.), C. H. Eckert (min. lab.).) E. A. Greene (elec. design), M. H. Murphy (least sqs. elec.), B. W. Pick (thermo., th. of const.), R. D. Torrance (ast. and geod.), W. G. Tough (ast., and geod.), W. D. Walcott (surveying), H. Goodridge (ast. and geod.), O. H. Hoover (th. of const.), F. M. Macdonald (th. of const.), J. B. Ferguson (st. of materials).

To Be Taken

F. J. Cannon (dynamics), P. L. Fancher (dynamics), D. B. Gardner (dynamics), P. L. Stevens (dynamics), L. B. Tillson (anal. geom.), H. Raymond (trig.), B. Walton (trig.), K. A. Jefferson (anal. geom.), S. M. Richardson (algebra, trig.), G. W. Rutter (algebra), P. G. C. Campbell (dynamics), R. D. Jones (dynamics), algebra), F. L. Mills (algebra), F. W. Hutcheson (algebra, trig.), J. H. Curzon (thermo.), E. M. Abendana (astronomy), J. C. Christner (French).

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Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 24 TORONTO, JUNE, 1912 New Series Vol. VI, No. 2

THE UNIVERSITY OF TORONTO AND THE MINERAL INDUSTRY*

By H. E. T. HAULTAIN,
Professor of Mining Engineering in the University of Toronto

Part I

The Province of Upper Canada was founded under the Constitutional Act of 1791. During the preceding seven or eight years a United Empire Loyalist population had been sitting on the banks of the St. Lawrence, on the shores of the Bay of Quinte, in the Niagara Peninsula and on the shores of Lake Erie, and the population of the province at this time numbered about sixty-five thousand.

Seven years later, in 1798, a committee of the Executive Council, of the judges, and of the law officers of the Crown, recommended that five hundred thousand acres of land should be devoted to educational purposes, of which one-half should be reserved for the University, and that the University should be located at York.

In 1826 the Rev. John Strachan, M.A., Archdeacon of York, was commissioned to visit England and returned with a royal charter founding a university. The charter was dated the 15th of March, 1827, and on the 3rd of January, 1828, the new lands for endowment already selected were conveyed by letters patent to the Corporation of King's College thus created. Shortly afterwards, the Council of the College purchased at one hundred dollars per acre, one hundred and sixty-eight acres of beautiful park lands, on which have subsequently been built both the Parliament and University buildings.

King's College was opened in 1843 with these seven professorships: (1) Classical Literature, Belles-lettres and Logic; (2) Divinity, Metaphysics and Ethics; (3) Experimental Philosophy and Chemistry; (4) Mathematics and Natural Philosophy; (5) Anatomy and Physiology; (6) Law; (7) Surgery. The salaries of the professors in Classics and Divinity were £500 and of the other Arts professors, £450

A statute of 1844 provided for the establishment as soon as funds should be available, of chairs in (1) Hebrew and Oriental Languages; (2) Political Economy; (3) Medical Jurisprudence;

* This article by Professor Haultain is now appearing in the "Canadian Mining Journal."

(4) Music; (5) History; Geography and Antiquities; (6) Geology and Mineralogy; (7) Civil Engineering; (8) Architecture; (9) Painting; (10) Agriculture.

Little progress, however, was made in these appointments for want of sufficient funds, and much trouble seems to have been caused by disputes over religious matters. The Anglicans, Methodists, and Presbyterians were active fighters. We are told that Bishop Strachan and his friends attacked the University as a "godless institution."

In 1850 King's College became the University of Toronto, and again a special committee recommended the appointment of professors in Civil Engineering and in Geology, as well as in Agriculture and other subjects.

In 1853 the chairs of Natural Philosophy and Natural History were founded and John Tyndall was an unsuccessful applicant for the first and Thomas Huxley for the second.

In 1856 Professor E. J. Chapman was appointed Professor of Mineralogy and Geology, a position he held for forty-two years, retiring in 1898.

In 1858 the crowning stone of the beautiful Main Building was laid by the governor, Sir Edmund Walker Head. The original plans for this building were curtailed for want of money, and, notwithstanding, the cost considerably exceeded the appropriation. This seeming extravagance in the building was, as most friends of the institution now think, justified by the result. The Hon. Edward Blake, addressing, as Chancellor, the annual convocation in 1884, said, "We sometimes hear murmurs as to the wisdom of their erection, but those who know as I do—though I was but a young man at that time—all the circumstances of the University when that policy was adopted, know that these buildings were in a marked sense the sheet anchor of the institution in the storms which at one time threatened to subvert it." The new buildings were opened for academic purposes in 1859, and from this point dates an era of greater prosperity for the University; but it was not until nearly twenty years later that a further step was made towards the benefit of the mineral industry. The statute of 1844 provided for the establishment of a chair in Civil Engineering, but it was thirty-four years before this was carried out.*

In 1877 the Legislative Assembly, by Resolution, sanctioned the proposals for the permanent establishment of the School of Practical Science of the Province of Ontario. These proposals were in effect that the Government should utilize the teaching power of University College, which already existed for the like objects in four departments, and could be made applicable to the wants of this Science School; and in addition thereto should appoint a Professor of Engineering and such assistants in the several departments as might be required in supplementing the work of the College Professors.

* Most of this has been taken from "The University of Toronto and its Colleges, 1827-1906."—Edited by W. J. Alexander, Published by the Librarian, 1906.

."The position which it is intended the School of Practical Science shall satisfactorily occupy in the Educational System may be indicated as follows:—

Firstly—Students who have passed through the regular courses of the School will be enabled to prosecute professionally, (1) Engineering; (2) Assaying and Mining Geology; or (3) Analytical and Applied Chemistry.

With this view the Diploma admitting to the standing of "Associate of the School" will be granted in each of these branches after due examination.

In Engineering it is intended that the instruction shall afford a thoroughly scientific basis for operations in the field. In the absence of a machine shop and of facilities for visits to mines during session, visits to workshops and excursions during the long vacation will be taken advantage of. The establishment of a diploma for special qualifications in Assaying and Mining Geology, apart from the knowledge of these subjects incidental to the course in Mining Engineering is sufficiently called for by the necessity which exists for the development of the mineral wealth of the province. Students who pass through the course necessary to obtain this diploma will have acquired the knowledge requisite for inspecting and surveying mineral lands, as well as the ability to report accurately on the composition and value of economic minerals generally.

The importance of the study of Chemistry is now fully recognized, and in Canada, through the Public Analysts and otherwise, protection is being secured to consumers, while the producers are necessarily brought to recognize its importance. The course in Chemistry will be such as to fit the student for the position of Public Analyst or of Consulting or Resident Chemist.

Secondly.—It is proposed to furnish preliminary scientific training for students entering the professions of Surveying and Medicine. The certificate to be granted in Surveying will be attainable by one year's study, and it is intended that this should entitle its possessor to appear one year earlier for his examination as Provincial Land Surveyor."*

The School so constituted was opened on October 1st, 1878, with the following staff:—

H. H. Croft, D.C.L., Professor of Chemistry and Chairman of the Board.

E. J. Chapman, Ph.D., LL.D., Professor of Mineralogy and Geology.

James Loudon, M.A., Professor of Mathematics and Natural Philosophy.

R. Ramsay Wright, M.A., Professor of Biology and Secretary of the Board.

J. Galbraith, M.A., Professor of Engineering.

W. H. Ellis, M.A., M.B., Assistant to the Professor of Chemistry.

The first four were professors in University College.

* From the Prospectus of the School of Practical Science of the Province of Ontario. First Session, 1878-1879.

It will be seen from this that from the very start the "School," as it was then known, was prepared to do much for the mineral industry. Not only was Engineering to include Mining Engineering, but there was a special course in Assaying and Mining Geology with a diploma attached equal in dignity to the diploma in Engineering. The Professor of Mineralogy and Geology was a remarkable and interesting man, a skilful fencer and a poet, as well as a scholar and teacher. He was educated mainly in France and partly in Germany, enlisted in the French army, and served an actual campaign in Algiers. He was also Professor of Mineralogy in University College, London, before coming to Toronto. He was a voluminous writer on Canadian Geology, on Assaying, and on Blowpipe Analysis. This course in Assaying and Mining Geology remained in force until the session of 1892-93, when it was replaced by the department of Mining Engineering; but I can find no record of any student having earned a diploma in this course.

The course in Analytical and Applied Chemistry appeared to be unpopular, as the records show that no diploma was issued in this course until 1890, by which time seventy-nine diplomas had been granted in the course in Engineering.

This course in Engineering would appear to be the most remarkable development in the history of the University, remarkable alike in the rapidity of its growth and in the consistency of its development. The central figure, in fact an isolated figure, in this development is that of the Professor of Engineering, afterwards Principal of the School and later when it was absorbed into the University, Dean of the Faculty of Applied Science and Engineering. It is probable that no other large department of any University in Canada has grown with such rapidity, nor has any other department of the University of Toronto with a live activity, departed less from the general direction laid down for its growth in its early stages. That the growth is so strong and so persistent is evidence of the closeness of the course to the needs of the country. This general engineering course is the backbone of the work that the University is doing for the mineral industry and will continue to be so.

John Galbraith graduated in Arts in the University of Toronto in 1868, winning, in his course, the Prince of Wales Prize for General Proficiency, and the Gold Medal in Mathematics, besides other prizes. The following years were spent in a variety of engineering work in both the mechanical and civil branches.

He was appointed Professor of Engineering in 1878. For the first few years of the School's existence he did all the Engineering teaching, including drawing and surveying.

W. H. Ellis, M.A., M.B., who had been associated with the School from the start, was appointed Professor of Applied Chemistry in 1882. In 1889 L. B. Stewart, Ph.S., D.T.S., joined the staff as Lecturer in Surveying, and the following year two of the School's own graduates returned, C. H. C. Wright as Lecturer in Architecture, and T. R. Rosebrugh as Demonstrator in the Engineering Laboratory.

In this year the School was affiliated to the University, the Professor of Engineering was appointed principal and the management of the School was transferred to a Council, consisting of the teaching faculty of the school and not including the Arts professors, who continued, nevertheless, to give instruction in their respective subjects to the School students. From this time on there was a steady growth in the staff until the present. There are now twenty-eight professors, associate professors and lecturers in the Faculty of Applied Science alone, besides a large number of demonstrators and fellows. This is in addition to the Arts professors in Mathematics and several other subjects, who still teach the Engineering students.

The first prospectus of the School does not contain the name of the Professor of Engineering; he was appointed after its issue, but in time for the first session. The first syllabus of the course in Engineering is very different from the one drawn up after his appointment. The syllabus of the second prospectus remains to the present the main framework of the department of Civil Engineering. It has grown, it grew continuously, it has been elaborated and to some extent modified, but the main lines have remained. The course to-day resembles the course of 1880 as the mature oak does the sapling. The latest change in the course, by some considered a radical departure, the addition of four lecture courses in business and finance is simply the blossoming of a bud that was shown to me many years ago and was probably a suppressed feature of a much earlier stage.

The main features of the course are, a groundwork of pure mathematics, a broad training in principles, followed by illustrations of the applications of the principles. The practice of Engineering is left to be learnt in the field. The exception to this is in surveying and draughting, and chemistry, where the student is given sufficient of the practice to make him a useful man in these subjects immediately on graduating. Engineering is so wide and the time of the academic period so limited that very much that would be desired must be left out of the course. Everything has been made subservient to the idea of the application of principles. Mathematics is for the preparatory mental training. The heavy course in principles keeps their application always in view. To this is added facts, methods and processes sufficient for the course in the application of principles. As the time is so short only the application of main principles can be illustrated. The whole is designed to enable and cause the boy to go on after graduation with the training which has only been commenced in the University. "We do not make engineers" has been the oft reiterated statement for thirty years of the Professor of Engineering; "We prepare them to become engineers."

Laboratories have been added, but not workshops, laboratories for the illustration and examination of principles. Only draughting, surveying, assaying and chemical analysis have their equivalent of shop work, but in each of these the elucidation of principles takes

precedence over the practice. There has been a splendid and careful development of laboratories in every direction.

The duration of the course was three years and in each year there were twenty-five weeks of actual teaching time, the summers were to be spent at work in the field. Examinations were held at the end of each session and the diploma of the School was granted on the satisfactory completion of the course.

After a graduate had spent three years in the actual practice of his profession, two years of which must have been on the construction and operation of engineering works as distinct from surveys merely, he could become a candidate for the degree of C.E. of the University, which was granted after the candidate submitted a satisfactory essay with drawings and estimates. This regulation was afterwards enlarged to include the degrees of M.E. (Mechanical Engineer). M.E. (Mining Engineer), and E.E. (Electrical Engineer). These degrees have not been popular with the graduates, the trouble being that anybody can put these letters after his name, with the result that it is generally the impostor who does so. But the intention of the University is well worthy of notice.

A degree that called for three years of actual work in the field is something very unusual and it is a great pity that circumstances should have belittled the use of these letters.

In 1892 an optional fourth year was added to the three years' course, and on the satisfactory completion of this year the degree of Bachelor of Applied Science (B.A.Sc.) was granted to the candidate by the University.

Some of the regulations governing the granting of this degree were as follows:

3. Each candidate shall prepare a thesis based on the results of his Fourth Year work in the said School of Practical Science for the approval of the University Examiners. This thesis is to be accompanied by all necessary drawings, specifications, tables and estimates.

4. Candidates will be required to select two subdivisions in any one of the following groups, and to pass such written and oral examinations on the subjects selected as may be prescribed by the University examiners.

A.—Astronomy.
Geodesy and Metrology.

B.—Architecture.
Strength and Elasticity of Materials.
Hydraulics.
Thermodynamics and Theory of Heat Engines.
Electricity and Magnetism.

C.—Industrial Chemistry.
Sanitary and Forensic Chemistry.
Inorganic and Organic Chemistry.

D.—Mineralogy and Geology.
Metallurgy and Assaying.

As the laboratories in all departments have grown the work of this fourth year became largely laboratory work. The students had the opportunity to specialize along their own lines and it was a very satisfactory arrangement.

The three year course for the diploma has now been done away with and students commencing during the past three years have entered on a four year course leading to the degree of B.A. Sc. This has permitted a re-arrangement of the curriculum and somewhat reduced the freedom of the fourth year. This was necessary as the work of the first three years had become much overcrowded.

It is hoped that before long an optional fifth year leading to a higher degree will be added.

In 1880 the diploma of the School was granted in "Engineering" and the studies could be pursued along three optional lines, Civil, Mechanical and Mining. In the session of 1890-91 this was subdivided into (1) Civil Engineering (including Mining Engineering), and (2) Mechanical Engineering (including Electrical Engineering). The following year Architecture was added. In 1892-93 Mining Engineering became a separate course and Civil Engineering "included" Sanitary Engineering.

At the present time the separate courses stand as follows:—

1. Civil Engineering.
2. Mining Engineering.
3. Mechanical Engineering.
4. Architecture.
5. Analytical and Applied Chemistry.
6. Chemical Engineering.
7. Electrical Engineering.
8. Metallurgical Engineering.

In 1880 the fees for the course paid by the student amounted to $160. This has been raised from time to time until it now amounts to $450. The standard of scholarship required for entrance has also been steadily raised. Despite these facts the growth in attendance has been rapid and steady.

The Government Blue-book covering the work of the University for the year ending 30th June, 1911, shows 779 students in the Faculty of Applied Science, and Engineering, of whom 99 were in the department of Mining Engineering.

The distribution of the students in the different subdivisions of the University was as follows:

University College—Arts	1086
Victoria College—Arts	516
Trinity College—Arts	140
St. Michael's College—Arts	46
Medicine	567
Applied Science and Engineering	779
Household Science	101

Education	262
Forestry	46
University of Toronto—Candidates for Ph.D., M.A., Dentals, Vets., etc.	576
Total	4112

Of this large number 1,018 were women and 3,094 were men. As there were 311 women students in University College there were more men students in the Faculty of Applied Science and Engineering than in any other subdivision of the University, though the combined group of Arts students in the various colleges would, of course, outnumber them.

President Falconer in an article contributed to the "University Monthly" in 1909, said: "Unless all omens fail the Faculty of Applied Science will soon become the second in size in the University and may creep up upon the Faculty of Arts, though Arts has such a lead that it will probably hold the first place for many years. During the last two years, not including the present, the ratio of increase in the Faculty of Applied Science has been thirty-two per cent., a larger proportionate increase than in any other Faculty.

"This Faculty has developed healthfully and in conformity with the demands of the country. Ontario has become a great manufacturing province without, at the same time, ceasing to develop its agriculture. The Agricultural College at Guelph is a splendid evidence of the good hope that lies before our farming population. For the other side of our life we also need leaders—in opening up new country by railways, in constructing large works, in developing mines. For producing men who will direct these activities there is the Faculty of Applied Science, formerly known as the School of Practical Science.

"A distinction must be kept clearly in mind. The aim of the Faculty of Applied Science is not to be confounded, as is sometimes done, with the work of technical education. The latter consists on the one hand of giving artisans and the youth in school instruction in the scientific principles that underlie the various trades in which they may be engaged, and on the other hand of instruction in the principles and technique of the actual trades. Technical education is meant for the man who whether as foreman or skilled workman, is engaged in some trade.

. . . .

"In the Faculty of Applied Science, however, students are being trained who will become the directors of the works in which the technically trained men will be employed."

(*To be continued*)

CONCRETE IN SEWER CONSTRUCTION

By W. J. Baird, B.A. Sc.

The superior qualities of concrete as a structural material are being more fully realized every day. In almost every kind of structural work it is competing successfully with older and better known materials. When any new material is introduced into the field of engineering, it has to undergo a period of trial, in which it receives much undue criticism owing to failures due more to inferior design and careless workmanship, than to any inherent defect in the material itself. Concrete was no exception to this rule. In the case of most kinds of work in which concrete has been used, its capabilities are now well-known, the methods of design are now fairly familiar to the engineer, and concrete structures can be built with at least as much assurance as to their safety and reliability as is possible with any other material.

In one class of work, however, concrete has not yet reached that safe and unassailable position in the ranks of structural materials that it has in many other classes and that its advocates claim is due it in this. That is in the use of concrete as a material for sewer construction. Concrete has been used for many years in the building of sewers, but cases of failure of concrete sewers have been so numerous and evidences of its reliability so conflicting, that there is even yet considerable doubt as to its adaptability under certain circumstances, and to its relative advantages compared to brick and vitrified clay pipe, the other most commonly used materials in sewers.

This condition of affairs arises from several causes; firstly, the fact that the work is covered up soon after completion, often makes it difficult to discover whether any subsequent failure was due to defective material, or to an accident arising from some combination of circumstances which it was difficult to foresee and make provision for; secondly, there are few classes of work in which apparently trifling defects, such as insufficient mixing of concrete or misplaced reinforcement, may lead to such disastrous results; thirdly, when a concrete sewer fails, the fact is advertised far and wide over the country by people who are interested in the sale of other sewer materials, such as vitrified clay products.

Concrete sewers have been in use for many years in Europe, and to a lesser extent in America. Paris, France, has probably more miles of concrete sewer than any other city. Brooklyn was one of the first American cities to use cement sewer pipe to any great extent; for many years their specifications required concrete pipe to the exclusion of other kinds. Wilmington, Delaware, was one of the first cities to construct monolithic concrete sewers. Many of these early sewers were constructed of natural cement concrete. Some of these have failed, and these failures have had a tendency to put concrete into disrepute as a safe and economical material. Since the introduction of Portland cement concrete into common use, however, many sewers have been constructed of Portland cement concrete, which seems to fulfil all the requirements of a

perfect sewer. Among the cities that have used concrete sewers somewhat extensively might be mentioned,—Chicago; New York; South Bend, Ind.; St. Joseph, Mo.; Toledo, Ohio; Cleveland, Ohio; Wilmington, Del.; Great Falls, Mo.; Philadelphia, Pa.; Truro, N.S.; Toronto and Hamilton, Ont., and many smaller places in both the United States and Canada.

Notwithstanding their wide use, many municipal engineers are somewhat diffident about adopting concrete for sewers, even though they admit that concrete is usually somewhat cheaper than the other materials in common use, and they have no definite reason for supposing that it is inferior to brick or vitrified pipe. This is due, doubtless, to the somewhat prevalent idea, that concrete is susceptible to the action of chemicals in sewage, and that concrete sewers are inferior in strength and impermeability to those constructed of brick or tile.

In this article it is proposed to make some investigations as to how concrete sewers compare with those of other materials in:

1. Their ability to resist the disintegrating of chemicals liable to be present in the sewage or ground water.
2. Their ability to resist the erosive action of fluids passing through them.
3. Their general suitability as sewage carrying channels.
4. Their ability to withstand the external pressures and shocks to which they are liable to be subjected.
5. Their cost.

It is also intended to give a short description of the different forms of concrete sewers which have been constructed and some examples of sewers now in use in various cities.

Resistance to Chemical Disintegration

The ground upon which concrete as a sewer material has been most attacked, and upon which it still remains the most open to attack, is with regard to its ability or lack thereof, to withstand the action of chemicals with which it is liable to come into contact. The makers of cement sewer pipe confidently assert that their product is proof against, not only the somewhat diluted chemicals usually found in sewage, but also against the most powerful combination of chemicals that the ingenuity of a chemist could devise. On the other hand, the manufacturers of vitrified clay pipe and sewer brick spare no expense in providing possible purchasers of their products, with apparently incontrovertible proofs that concrete is not only liable to be disintegrated by sewage, but that it is also easily dissolved away by the action of pure water alone. The truth must lie somewhere between these two statements, just where, there is none too great a wealth of evidence to show.

The disintegrating agent may arise from the sewage or from external agencies, such as the ground water. In the first case the immediate agent of destruction may be in the sewage itself in the form of dilute acids or alkalis, or it may be in the form of gases given off by the sewage. This case shall be considered first.

An often-quoted example of the disintegration of concrete by sewage gases is in connection with the sewage disposal works at Hampton, England. The history of the case was given in a paper read by Mr. Sidney H. Chambers, engineer to the Hampton Council, to the members of the Concrete Institute. In connection with the hydrolysing chamber and the inlet channel it was noticed that the concrete was being decomposed. Upon examination it was found that the concrete that was always under water was perfectly sound, while that high above the water was only slightly affected. The area of maximum decomposition was included between the low and high water levels of the sewage. The concrete where it had been attacked by the sewage gases was found to be covered with a white chalky substance which analysis proved to be sulphur. The concrete under this, upon being analyzed, was found to contain a large percentage, varying from sixty-five to seventy-five, of sulphate of lime.

The explanation given for this ran as follows: the main erosive effect was at the varying liquid level, and was there dependent upon the amount of sulphuretted hydrogen in solution in the liquid. The gas was comparatively small in amount in the incoming sewage but increased as the liquid passed through the hydrolysing chambers owing to increased putrefaction. When the level of the liquid fell it left the concrete which it previously covered, wetted with a liquid containing sulphuretted hydrogen in solution. This wet surface was then exposed to the air which oxidized the sulphuretted hydrogen, forming sulphurous and sulphuric acids, which, acting on the concrete, changed the lime to sulphate of lime. The active agent was probably sulphurous acid as concrete is not affected much by sulphuric acid. When the liquid rose again the decomposed material was washed away, and a fresh surface exposed to the action of the sewage when the liquid fell again. It was the continuation of this cycle that led to the formation of the grooves at the varying liquid level.

The erosive effect on the concrete above the liquid level was dependent upon the sulphuretted hydrogen evolved from the liquid and mixed with the air supply. Some of this gas was dissolved by the moisture which was present on the walls and roof from evaporation and condensation; it was then oxidized by the air and decomposed the concrete, as described above.

The conclusions drawn from these investigations were, that gases in solution in sewage and those expelled from it do not act injuriously on Portland cement concrete, provided all the following conditions occur at the same time:—

1. A high degree of putrescence in the sewage.
2. A moistened surface which absorbs the putrid gases.
3. The presence of a free air supply.

This case has sometimes been quoted as direct evidence of the inferiority of concrete as a sewage-resisting substance, but if a close examination of the situation is made, it will be seen that there are extenuating circumstances which make the situation not as bad as it seems. In the first place, of the many sewage purification plants,

this is one of the few from which there has been like trouble reported; secondly, since, as it is distinctly intimated in the report, there is necessary before sewage gases can have any effect on the concrete, a high state of putrefaction, such as could never exist in a properly designed and constructed sewer, to attempt to introduce this as an argument against the use of concrete in sewers appears to be misapplied energy.

A somewhat similar case has been reported from Amherst, Ohio. Here the Ohio Quarries Co. have a small purification plant to care for the sewage of about eleven dwellings. This plant was built in 1905 and consists of a covered septic tank and continuous filter. Being so small there is quite a variation between the low and high levels of the sewage. Disintegration of the walls of the septic tank was noted in March, 1910, and was found to be most pronounced along the strip between the ordinary flow level and the high level caused by increased flow in times of storm. The writer gives it as his opinion that sewage will attack concrete if there is much putrefaction taking place, especially if the concrete is of anything but a dense impervious mixture.

In the reconstruction of a large sewer (15′ x 20′) in St. Louis about eight years ago, concrete was used both with and without a covering of vitrified bricks in adjoining portions of the sewer. The section covered by the vitrified brick seems to be the most satisfactory. The surface is hard and smooth and no appreciable wear can be detected. The surface of the concrete section not covered with vitrified bricks is completely pitted with small holes from one quarter of an inch to one half an inch in diameter and depth. The Portland cement mortar seemed to be partially disintegrated. When new, the mortar was allowed to harden for several days before sewage was allowed to pass over it. The cause of this pitting has not yet been determined.

In the proceedings of the Institute of Civil Engineers for November, 1908, Mr. Barnett described some investigations he made in connection with the detection of water losses in the Thurlmere Aqueduct, which supplies Manchester with water. The aggregate of the concrete was here composed of pure limestone, and it was found that where the limestone was exposed to the water, marked cuppings were visible, showing that the limestone was being dissolved by the water while the water was unaffected. Mr. Barnett made some tests to confirm this. He submitted a block of each of the following, limestone, cement mortar and neat cement, to the action of the water. He found that the limestone was the only one of the three to be appreciably affected, and it was found to have lost a considerable percentage of its weight.

It is a well known fact that water unites with carbon dioxide gas, forming an acid which reacts chemically with limestone. Hence, water which contains a quantity of this acid will have a destructive effect on limestone with which it is brought into contact. Since carbon dioxide is evolved wherever there is any decomposing organic matter, it is practically certain to be present in sewage. It would

appear to be a necessary precaution to exclude limestone from the concrete to be used in sewer construction. In the results of the experiments just mentioned may lie the explanation of the action of the St. Louis sewer. However, a more detailed knowledge of all the contributory circumstances would be necessary before any definite conclusion could be made.

It would appear that fear of the concrete being attacked by gases present in the sewage is ill founded, while before it could be decided as to the probability of the sewer being destroyed by chemicals in the sewage itself, an examination of the sewage to be carried and of the concrete aggregate would have to be made. However, it is evident that any sewage having a deleterious effect on a concrete sewer would have the same effect on the cement mortar of a brick, and to a lesser extent on the joints of a vitrified pipe sewer. That brick sewers are not altogether immune from the attack of strongly acid sewage is shown in the case of a sewer in Halton Borough, England, where a brick sewer was completely disintegrated by acids allowed to drain into it from silversmiths' and goldsmiths' workshops.

The opinion of municipal engineers as to the effect of sewage on concrete is far from unanimous. The mayor of Kansas City obtained the opinions of a number of prominent engineers, among whom were the city engineer of Jersey City, Mr. E. S. Rankin, C.E., and Alexander Potter, C.E., of New York, all of whom gave it as their opinion that the danger of sewage having any effect on concrete was inappreciable. On the other hand there have been published letters from several engineers, for instance, the city engineers of Terra Haute, Indiana, and Worcester, Mass., in which they gave as their decided opinion that concrete sewers are liable to be disintegrated by sewage. On the whole there seems to be little to justify the contention that concrete sewers are liable to failure from the attacks of chemicals in the sewage.

A common cause of the disintegration and consequent failure of concrete sewers is the presence of the sulphates, chlorides and carbonates of magnesium, calcium and potassium in the ground water. Of these the sulphates appear to be the most active. Cases of this nature have been noticed in the arid regions of the Western States and India, and in Prussia.

Mr. J. G. Jewett, of the U. S. Reclamation Service, gave before the American Society for Testing Materials in 1908, certain information regarding the effect of these alkaline charged waters on concrete culverts in Montana and Wyoming. Considerable disintegration was found to take place near the water line. This seemed to consist largely of the formation of crystals, which was accompanied by considerable expansive force. Experiments made by Mr. W. P. Headden, of the Fort Collins Experimental Station, indicate that cement concrete is very susceptible to the action of weak solutions of the above mentioned alkali.

Preliminary to the construction of a reinforced concrete pipe line in Idaho through alkali soil, some investigations were made to determine the probable effect of the alkalis on the concrete. A

test length of pipe was placed in a slough where it would be exposed to the action of alkali under the most severe conditions that could be devised. Up to the present, six months later, no effect that can be detected has developed. This experience seems to be somewhat unusual.

The case of the sewers at Great Falls, Montana, has been frequently referred to and is, probably, the most striking illustration of the deterioration yet considered. The City Engineer, Mr. C. W. Swearingen, was so impressed by the conditions that he requested an expert from the Montana State Agricultural College to report it. The report is embodied in Bulletin No. 60 of the Montana Experimental Station, from which the following extracts are taken:—

"The Third Street main sewer was built in 1890, the material used being Portland cement pipe of home manufacture made in molds and put in place after the cement had hardened. The sewer is oval, 20 inches by 32 inches. This sewer, after a comparatively short term of service, showed defects so serious as to necessitate rebuilding portions of it. The remaining portion of the sewer has disintegrated in many places and pieces of the pipe are gone.

"The Sixth Street sewer was constructed in 1892, circular in form with an inside diameter of four feet, being composed of two rings of brick laid on edge in 1 : 3 Portland cement mortor with an outside plaster coat one-half of an inch thick but not plastered on the inside. The masonry in the invert is disintegrated almost its entire length. There is no subdrain under or along the sides of the sewer."

The results of the examination are synopsised as follows:

(a) The disintegration and destruction of the cement was not due to adulteration or to the quality of the materials used.

(b) Though a limited chemical and physical action of the alkali salts may be a partial cause of the breaking down of the brick, yet the primary cause was that the bricks were too soft, and not fit for sewer construction.

The analyses embodied in the report show that the maximum disintegration occurred where the greatest percentage of alkali salts showed in the soil, and that the ground waters were leaching the alkalis from the soils and depositing the salts along the sewer. The authors of the report consider the use of concrete sewers in alkali soils as inadvisable, where it is not possible to drain all the ground water from the exterior of the sewer. They recommend that drain tile be placed in the bottom of the trench and covered with gravel or crushed stone, and that similar drains be placed around the barrel of the sewer to provide drainage for the storm water, in order that it may not come into contact with the sewer. Where these precautions cannot be taken they "unhesitatingly recommend that cement pipe be not used."

At Lake Loveland in 1894 a tunnel for conveying water was lined with concrete. Ground impregnated with alkalis was met with in large quantities, but by providing large and efficient side drains it was possible to keep the ground water away from the con-

crete, with the result that fifteen years later the concrete is apparently as good as new.

In connection with some reclamation work in the United States it was discovered that the only convenient sand supply contained three per cent. of alkalis, which had a deteriorating effect on the concrete in which it was used. Apparently in some regions it would be necessary to investigate the composition of sands intended to be used in making concrete.

In connection with all these failures it has been noticed that the more porous a concrete is, the more liable it is to disintegration by alkali waters, and so a dense mixture of concrete should always be obtained where it is liable to be attacked by alkalis.

Dr. Rudolph Hering, in discussing the paper read by Mr. Anderson, before alluded to, describes a rather peculiar failure of a concrete sewer in Prussia. In this case the sewer had been laid in peaty ground which had as one of its most prominent constituents, iron pyrites. It was discovered that this pyrites was providing the sulphur for the formation of sulphurous acid which was attacking the concrete. In a similar case at Charlottenberg the concrete was protected by three layers of asphalt paper covering the concrete entirely.

At the annual convention of the Illinois Society of Engineers and Surveyors, the Committee on Sewers gave as their opinion that there was little to fear of concrete being injured by alkali soils in arid regions, and in any case solvents would prove as injurious to the cement mortar of a brick sewer as to a concrete sewer. Upon what evidence this conclusion was based is not recorded.

From the foregoing it may be concluded that if concrete sewers are to be built in alkali regions, some, or preferably all of the following precautions must be observed:

1. The ground in the immediate vicinity of the sewer must be so well drained that very little, if any, ground water is allowed to come into contact with the sewer.

2. The concrete must be made as nearly impervious as possible by using dense mixtures of concrete or by the addition of some waterproofing compound.

3. The outside of the sewer may be protected by means of some waterproof coating, such as asphalt or tar paper.

As for the contention sometimes made, that concrete is soluble in pure water, this seems too absurd to require any denial, in view of the fact that there are large numbers of concrete structures successfully withstanding the dissolving action of all kinds of ordinary water. On January 23, 1908, Mr. G. C. Wheat read before the Iowa Brick and Tile Association a paper in which he attempted to prove that concrete is soluble in water. He gave the results of some tests which he had made in which he submitted blocks of concrete to the action of distilled water. He found that the concrete after being about ninety hours in the water, had lost a small percentage of its weight. From this he concludes that the concrete, if left in the water long enough, would be entirely dissolved, assuming

apparently, that the rate of solution would remain constant. But, as Mr. P. Gillespie points out, in referring to this paper, the rate of solution is probably not constant, and the loss in weight may be due to the dissolution of some minor soluble elements in the concrete, such as calcium sulphate, which is added in small quantities to cement in order to retard the set. Apparently the loss in weight of concrete due to the action of comparatively pure water is inappreciable.

Ability To Resist Erosion

There has been an idea prevalent for many years among the builders of sewers that concrete is inferior to sewer brick, in its power to resist the erosive action of sediment-carrying sewage. Just how this idea originated and how much foundation for it there is in fact, is difficult to say. But the result of the belief has been that about two-thirds of the concrete sewers constructed have had their inverts lined with some supposedly harder material, such as vitrified tile plates.

It is difficult to understand why concrete sewers should be less able to resist erosion than those constructed of other materials. In other structures, sidewalks for instance, concrete shows an abrasive resistance equalled by few, if any, other materials. Experiments to determine the relative powers of resistance to abrasion of the various materials used in sewer inverts are not numerous. One series of experiments have, however, been made by Mr. G. S. Rankin, and presented in a paper read before the American Society of Municipal Improvements.

In introducing the subject of the wear of sewer inverts Mr. Rankin instances the case of a brick sewer, six thousand feet long, which came under his observation in which the invert was completely worn through and had to be renewed at a considerable expense. He also quotes the following instances from Folwell's "Sewerage."

"A five and one-half foot two-ring brick sewer in Baltimore, twenty-five years old, was recently found with its invert cut completely through for a width of twelve to fifteen inches and badly worn to the height of two feet. In Omaha, brick sewers, the wear of which is usually eighteen inches to twenty-four inches wide, became from two to five inches deep in twelve years."

In Newark, N.J., a brick sewer built in 1886, size forty-five inches by sixty-nine inches, with a grade of 1.6%, was found to have its invert almost completely worn through in 1910. As a result of this wearing, it has been the custom to line the lower third or quarter of the cross-section with vitrified paving brick. The only test required was that the brick should not absorb more than two per cent. of its weight in water after being thoroughly dried, and immersed in water for twenty-four hours.

Experiments were made by Mr. Rankin with the idea of determining the relative wearing qualities of several materials and their consequent suitability as materials for sewer inverts. The samples were first tested for absorption and then placed on a rubbing machine such as is used in stone yards for rubbing blocks of stone. The

samples were all twenty pounds in weight and were left on the machine twenty minutes, the velocity of the rubbing machine being at the rate of twenty-one feet per second. The results of the experiment were as shown in the following table:—

No.	MATERIAL	% Gained by Absorp.	% Lost by Abras.	Ratio Absorp. to Abras.	Life of Invert in years	Remarks
1	Vitrified Shale Brick.....	1.36	2.00	1 : 1.47	324	The life of the invert in years is calculated by assuming the life of No. 8 as 10 years.
2	Vitrified Shale Brick.....	2.15	3.35	1 : 1.56	193	
3	Vitiified Shale Brick.....	3.60	3.42	1 : .95	189	
4	Vitrified Shale Brick.....	4.28	5.92	1 : 1.38	109	
5	Shale Sewer Brick.......	13.18	27.31	1 : 2.07	24	
6	Building Brick..........	7.39	20.41	1 : 2.76	31	
7	Building Brick..........	10.19	44.74	1 : 4.39	15	
8	Building Brick..........	18.91	64.74	1 : 3.42	10	
9	1 : 2 Cement Mortar....	11.86	4.41	1 : .37	147	
10	1 : 2 : 4 Grav. Concrete	6.65	3.82	1 : .57	169	
11	1 : 2 : 4 Grav. Concrete	5.10	3.35	1 : .66	193	
12	1 : 2 : 5 Stone Concrete	7.40	8.62	1 : 1.16	75	
13	Vitrified Tile...........	1.34	4.47	1 : 3.34	145	
14	Vitrified Pipe...........	4.47	6.11	1 : 1.37	109	
15	Vitrified Pipe...........	1.72	4.55	1 : 2.65	142	

TABLE No. 1

Specimens Nos. 1—4 were vitrified shale paving brick selected for their variation in absorption. No. 5 was a small shale brick made for use in sewers. Nos. 6, 7, and 8 were different makes of building brick, also selected for their variation in absorption. Nos. 9, 10 and 12 were made from the mortar and concrete, being used in the construction of a sewer at the time of the experiment. No. 11 was a section of concrete pipe furnished by the Lock Joint Pipe Co., and was about one year old. No. 13 was a tile used by the same company for lining their pipes with, when required by engineers. Nos. 14 and 15 were samples of salt-glazed vitrified pipe.

While admitting that these experiments are far from being complete and exhaustive, Mr. Rankin draws the following conclusions from them.

1. "That for similar materials, although there is considerable variation in the ratio, the abrasion in every case except No. 12 increases with the absorption, that gives a fair idea of the wearing qualities of the materials.

2. "The additional cost of lining a brick sewer is warranted, although the two per cent. requirement of the Newark specifications seems unnecessarily severe.

3. "The concrete sample compares favorably with paving brick and it would appear unnecessary to line a concrete sewer.

4. "Tile pipe is generally not as durable as concrete pipe."

The last two clauses are particularly noteworthy in connection

with the subject under discussion, and are somewhat contrary to the belief commonly held by many people who cannot be accused of being prejudiced against concrete in any way.

Tests by Mr. C. C. Clarke tend to indicate that the best proportions to resist abrasive forces are 1 : 2 for Portland cement mortar. This fact might be made use of in plastering the inside of concrete sewers, as is sometimes done.

Mr. Hermann describes some investigations into the wearing power of some sewers in St. Louis. The grades of these sewers range from .2% to 2%. The vitrified clay pipes show no appreciable wear after thirty-five years use. These are usually laterals carrying small amounts of sewage, but carrying a considerable quantity of strong acids and scalding water. The vitrified brick sewers also show no appreciable wear but they have been only about twelve years in use. One course of square-edged vitrified bricks are used for the bottom quarter of the circular sewers and in those of other shapes are carried up six inches above the ordinary foul water flow.

The inverts of sewers built of common bricks begin to show some wear after about three years of service, and after about thirty-five years the first row of brick has nearly disappeared. The wear is found to vary greatly, in sewers of different size, shape and grade, and with the quality of the sewage and the hardness of the brick.

Mr. W. C. Parmeley considers that a more resisting surface can be got from concrete than from any but the hardest vitrified brick.

In Duluth, Minn., the grades of the sewers are exceptionally steep and it has been found impossible to keep sand and small stones out of the sewers. Concrete sewers have been proven to be more durable than brick. In one case on a very steep grade, granite flags were laid in cement mortar. Two years later the granite was found to be worn away, leaving ridges of mortar between the flags showing the concrete to be more durable than granite. Mr. T. J. McGillivray, city engineer of Duluth, says that he finds that the gravel and stones washed into the sewers in time of storms abrase the "skin" of the vitrified clay sewer pipes, which results in the speedy disintegration of the pipe. This is a somewhat unusual circumstance, as vitrified pipes are usually considered fairly hard and durable under almost every condition.

In the construction of a sewerage system at Louisville, Ky., all sewers were lined when the size and grade were such that a velocity of eight feet per second would be likely to be exceeded. In small circular sewers of twenty-four to thirty-six inches diameter the lining was vitrified pipe, while in larger sewers the bottom and sides were lined with vitrified bricks laid in cement mortar.

In the construction of the intercepting sewers in Toronto, brick was used in part, and brick lined concrete in the rest. The use of brick in this case seems to have been more due to the pressure brought on the City Council by the brick interests than from any belief in the superiority of brick as a material for sewers.

In view of the extra cost involved in the use of vitrified bricks and their doubtful efficacy, the use of vitrified brick lining for sewers appears to be doubtful economy. It is always advisable to examine the grade of a sewer and the consequent maximum velocity of the sewage before it is decided whether to line it or not. In case the maximum velocity exceeds about eight to ten feet per second, it would seem to be good practice to line the sewer.

General Suitability

There are two qualities which any material must possess before it can be successfully applied to sewer construction, that have not yet been taken up in detail. These are water-tightness and smoothness of surface.

Concrete is eminently fitted for sewers in that it is capable of being constructed with a very smooth surface, and all special construction necessitating the use of sharp angles and curves can be made perfectly true to shape, thus offering little resistance to the flow of sewage. This is of great advantage where there are many sharp turns in the sewer and the grade is slight.

In order that a sewer may fulfill the duties for which it was built, it must have such a form and be laid to such a grade, as to cause a sufficient velocity in the water to carry along any solid materials that may be in the sewage. Upon reference to literature on hydraulics, we find that a velocity of water in a pipe from two and one-half to three feet per second is necessary in order to cause such materials as sand, gravel, etc., to be carried along. According to Ogden, in his work entitled "Sewer Design," if a pipe has these velocities in it when flowing half full, it will have a self-cleansing velocity when only flowing partly full. Suppose that it is decided in designing a sewer that a velocity of three feet per second when the sewer is half full is the minimum allowable velocity. It is desired to find the minimum grade that will produce this velocity. For the sake of illustration the cross-section of the sewer shall be considered circular.

The formula most used in computing the velocity of water is Chezy's.

$V = C\sqrt{RS}$ where

V = velocity in feet per second.

R = hydraulic radius.

S = size of slope angle.

C = constant depending on the slope, shape of cross-section, and roughness of surface. C is usually determined from Kutter's formula:—

$$C = \frac{41.66 + \dfrac{1.811}{n} + \dfrac{.00281}{s}}{1 + \left(41.66 + \dfrac{.00281}{s}\right)\dfrac{n}{\sqrt{R}}}$$

where "n" is a coefficient of roughness depending on the roughness of the surface with which the water is in contact, the other symbols having the same significance as in Chezy's formula. Before proceeding any farther it is necessary to fix on the value of "n" to be used in the above formula. Merriman gives the following values for "n."

n = .011 for cement mortar.
n = .013 for good brick work.
n = .015 for unclean surfaces in sewers.

In Ogden's "Sewer Design" the following values are given:—

n = .011 for cement mortar and cement pipes well jointed and in good condition.
n = .012 for tough cement mortar.
n = .013 for well-laid brickwork.

In the design of the concrete sewers at Louisville, Ky., a coefficient of n = .013 was used. It would appear that for concrete sewers in fair condition a coefficient of n = .012 would be reasonable, while in brickwork a value of n = .015 would be all that could be expected. This difference in the values of the coefficients will have the effect of producing different results in determining the minimum grades in order to produce the minimum velocity in the two different types of sewers.

The minimum grades for pipes of various diameters, consistent with the afore-mentioned assumptions are given in the table below:

Diameter of Pipe in Feet	Minimum Grade	
	Concrete n = .012	Brick n = .015
2	.00150	.00260
3	.00085	.00140
4	.00055	.00092
5	.00042	.00065
6	.00034	.00053
7	.00027	.00043
8	.00022	.00037
10	.00017	.000275

TABLE No. 2

Of course these figures hold true for circular sewers flowing either half or full, but the principle involved is the same whatever be the shape of the cross section and the depth of water flowing through the sewer. That is, that concrete sewers can be laid on flatter grades than bricks for the same minimum velocity.

This table shows that in a case where the outlet has to be kept as high as possible while preserving a minimum grade in the sewer, a considerable saving in excavation might be effected by using a concrete sewer in preference to a brick one. Thus, for a five foot sewer the saving in grade would be .023 ft. per hundred feet. This in a mile of sewer would mean a saving in excavation at the end of the mile of

1.12 feet. The saving in the cost of a mile of excavation in rock would be (taking the cost of rock excavation as being $3.00 per cubic yard) approximately $1,900. This in a sewer several miles long would affect a considerable saving. For earth excavation, however, the saving would probably be not more than one-sixth of this amount. Also in low level sewers where the sewage has been pumped a reduction of the grade would mean a reduction in the height which the sewage has to be raised.

The difference in roughness of the interior surface of the two different types of sewer results also in a difference in their carrying capacity. This is shown very clearly by the accompanying curves. These show that for any particular diameter of pipe and grade, the concrete sewer has a much greater carrying capacity than the brick sewer. Although the cases here illustrated are very limited in their application, the sewers being supposed of circular cross

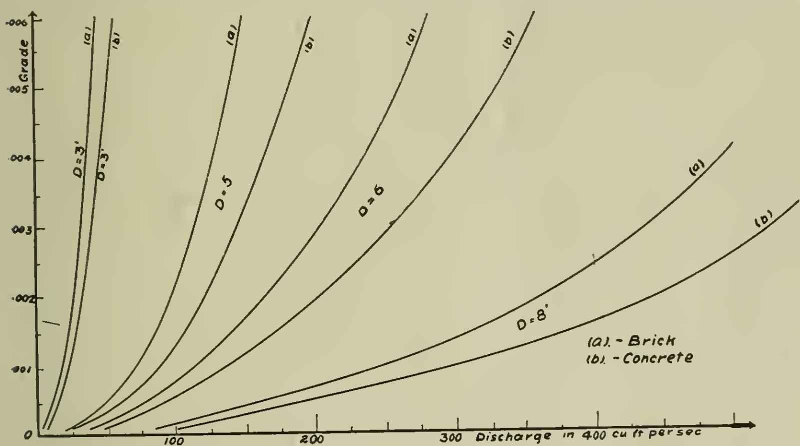


FIG. 1.

section and to be flowing full, the fact remains that concrete sewers have a greater carrying capacity than brick sewers of the same size whatever be the shape of the cross section, or the condition of flow in the sewer. Some may not agree that there is as great difference as is found by using values of n = .012 and n = .015 for concrete and brick sewers respectively, but it is quite apparent that a higher value would be used for brick than for concrete sewers, and the values above-mentioned are about as good as can be obtained at this stage of our knowledge of the flow of water in pipes. In the foregoing computations the usual assumption has been made, that, so far as the hydraulics of the case are concerned, sewage is practically all water.

It has been frequently asserted that concrete not being an absolutely water-proof material in itself, concrete sewers would be defective in that they would be liable to admit ground water and also to allow the sewage to leak out, thus polluting the ground in the

vicinity of the sewer. This is, apparently, erroneous, when one considers that there are numerous concrete pipe lines all over the country which convey water, sometimes under considerable heads, without undue leakage. This would seem to indicate that it is perfectly possible to make concrete waterproof.

It is scarcely necessary to mention the numerous different methods of water-proofing concrete here. These details can be learned upon reference to any work on concrete. However, the first essential of a waterproof sewer is a carefully graded and mixed concrete. A careful study of the aggregate to be used should be made and an effort should be made to have as dense a mixture of concrete as it is possible to obtain. Also, especial care should be taken in the mixing, placing and bonding of the concrete. If this is done an important step towards obtaining a waterproof sewer has been taken. Lime and fine clay have sometimes been used in waterproofing concrete sewers.

A concrete sewer was constructed in Denver beneath the level of the La Platte River. An effort was made to have the sewer waterproof in order to prevent seepage of the ground water. The contractor was allowed to adopt any means his fancy suggested for waterproofing the concrete, but he had to guarantee the sewer to be waterproof a year from the time of completion. The contractor used Toxement, a patented waterproofing compound, using three pounds for each sack of cement. Reliance was placed on the concrete mixture for obtaining a uniform distribution of the compound. A satisfactory result is said to have been obtained.

Preliminary to the construction of the Louisville sewerage system the commission in charge made some tests for finding the most impervious concrete. Concrete pipes were tested for about seven hours under a pressure of about fifteen pounds per square inch. The concrete used consisted of one part of cement to two parts of Ohio River sand to four parts of Ohio River gravel. Tests were made on plain concrete and on concrete containing lime, clay and various precentages of several waterproofing compounds. The best results were obtained by the use of four per cent. Medusa and four per cent. Toxement Waterproofing Compounds, the seepage in each case being zero. With the 1 : 2 : 4 concrete the seepage was 6.30 cubic in. per square inch of surface.

In a part of the construction of these same sewers a fine clayey moulding sand was used for ten per cent. of the sand 1 : 2 : 4 mix. The sand was thoroughly mixed with water and then mixed with the rest of the sand and the cement. As far as can be seen this method is satisfactory.

So far as the permeability of concrete sewers and their consequent liability to leakage is concerned, there seems to be little cause for alarm, provided reasonable care is used in the construction.

Stresses Due to External Pressure

In designing sewers it is usually customary to consider the sewer as having to sustain all the dead load of the fill over it and also

all the live load that is likely to come on it when the amount of cover is less than four feet. When the amount of fill exceeds four feet the sewer is supposed to be capable of sustaining the weight of the fill and a certain percentage of the live load, this percentage varying from one hundred at four feet deep to zero at about fourteen feet, at which point the live load is supposed to cease to have any effect. These figures are only assumptions, although probably very reasonable ones, since it is difficult to arrive at any definite conclusions from theoretical considerations alone owing to the uncertain nature of earth pressures.

An empirical formula for determining the amount of pressure liable to come on the sewer from the dead and live loads runs as follows:—

$$\text{Dead Load} = 83d - 2.54d^2$$
$$\text{Live Load} = 1000 + 3.72d^2 - 112d$$

where d = depth of fill over sewer.

According to this formula the live load ceases to have any effect when the depth of fill exceeds about 15 feet.

In designing sewers considerable allowance has to be made for the uncertain stresses liable to be set up by irregular settlements of the foundations, and quite large factors of safety are usually considered necessary. A very complete analysis of the subject of stresses in circular sewers and culverts subjected to earth pressure is given by Prof. A. N. Talbot in a bulletin issued by the University of Illinois. In introducing the subject the professor says: "The stresses developed in rings and pipes subject to external pressure, are, of course, dependent upon the bending moments developed. As the exact load coming on the sewer and its distribution over the surface are difficult to determine, the bending moment is in general quite uncertain. The amount of load and its distribution over the surface, and therefore the bending moment on different parts of the ring depend upon a number of conditions, such as the nature of the earth used in filling, the method of bedding the pipe, the manner of tamping the earth at the side, the amount of lateral restraint or pressure of the earth, the conditions regarding moisture, etc." These conditions of loading may include:—

1. A concentrated load at the crown.
2. A vertical load distributed uniformly over the horizontal section.
3. A distributed vertical load together with a horizontal load distributed perpendicularly over the sides of the ring.
4. An oblique load, such as may prevail in a sewer trench, a slip of earth causing pressures to be set up in the sewer that are not provided for in any of the previous cases.

Mr. Talbot made a large number of tests on plain and reinforced concrete rings and pipes, comparing the results of these tests with those derived from formulae. An examination of his results shows the chief benefits to be derived from the reinforcing of concrete pipes would be in lessening the liability of sudden failure from shock and pressures not otherwise provided for, and in permitting

the use of a thinner shell for the pipe. The reinforcement should also be taken into account in fixing on a proper factor of safety. The main lesson to be derived from his tests is, however, the advisability of providing a uniform bedding for the sewer and an evenly distributed, well-compacted, filling, in order that the pressures on the sewer may be distributed and not concentrated.

So far as the small number of tests made upon the relative strength of concrete and vitrified clay pipes admits of a conclusion the resistance of the pipes against outside compression varies to a great extent, even with pipes of the same size, and made of the same materials. However, the concrete pipes seem to give slightly higher average values than vitrified clay pipes.

Average results derived from experiments are not very conclusive, and since no sewer is stronger than its weakest length, sewer pipe of material with a fairly constant and uniform strength is preferred to one of higher average strength, but which on account of its brittleness, is more liable to sudden failure. This is one drawback to the use of vitrified clay pipes of large sizes. Their brittleness renders them liable to breakage due to careless handling or to sudden shocks from various causes.

Mr. Alex. Potter gave before the Boston Society of Civil Engineers a description of some of the difficulties encountered in the construction of about one hundered and fifty miles of vitrified pipe sewers in Newark, N.J. In this sewer system, twenty-four and twenty-six inch tile sewers were laid, some in wet trenches where they had to be supported by timber foundations. The discovery of the failure of a two-hundred foot section of twenty-four inch pipe led to an inspection of the entire system. It was found that in the cases of the larger sizes, a large number of the pipes were cracked, and in a few cases had completely collapsed. All these breakages were in rock trenches, or in places where broken stone or gravel foundations had been used. The pipes laid in quicksand or on timber foundations were found to be intact. Mr. Potter is of the opinion that no vitrified pipe larger than 20 inches diameter should be laid without a concrete foundation. The extra cost of the concrete foundation should be taken into account in estimating the relative cost of vitrified pipe sewers and those of other materials for sewers these sizes.

Tile pipe is now made in various sizes up to 42 inches in diameter, but the concensus of opinion among engineers seems to be that their use is inadvisable when a sewer of greater diameter than 20 inches is required. The ability to use steel reinforcement, either in pipes or monolithic construction, to take up the tensile stresses, would seem to be an important point in favor of the use of concrete for sizes of greater diameter than twenty inches.

In the construction of sewers in Richmond, Ind., vitrified tile pipe was used for sizes up to and including eighteen inches diameter, while concrete was used for sewers of from twenty inches to fifty-four inches in diameter. The twenty-inch pipe was not reinforced

and was found to be unsatisfactory; the larger sizes were reinforced and gave good satisfaction.

The strength of the plain concrete pipes of small diameter does not seem to be much different than that of tile pipes of the same diameter, while for the larger sizes good design and proper construction is all that is required in order to obtain a thoroughly strong and reliable concrete sewer.

Comparative Costs

The relative costs of sewers of different materials in any particular case, depends largely on circumstances peculiar to that case, such as proximity to the source of manufacture. However, there are several general principles, which hold true in almost all circumstances, and are applicable to a greater or less extent under all conditions, which tend to make concrete sewers cheaper than brick ones of the same size. A brief discussion of these will now be made.

Within the past few years the price of brick has advanced about fifty per cent. while the price of cement has decreased about the same amount. The market price of broken stone and sand, while governed almost entirely by local conditions, has remained nearly constant.

About seventy-five per cent. of the weight of the entire masonry of brick sewers, that is, the bricks themselves, must be transported from the factory to the site of the work. A large cost is usually involved in freight and teaming charges. On the other hand in the case of a concrete sewer, frequently only about ten per cent. of the weight, i. e., the cement, has to be brought long distances, and since the quantity required is only slightly in excess of that required for brick masonry, the gain is still more apparent. The high cost of vitrified brick also tends to increase the cost of masonry structures.

Only skilled bricklayers can lay bricks for sewers, and skilled labor is expensive, while concrete can be laid by unskilled laborers.

Bricklayers have powerful unions, and a contractor is liable to be held up by a strike among his bricklayers, the possibility of which he has to allow for in his bid.

A brick wall must be built of sufficient thickness to contain the line of pressure near the middle third of the ring, in order to prevent cracking. This generally results in working the materials at a very low efficiency. For example, masonry that can safely withstand a pressure of from one to two thousand pounds per square inch is worked at a pressure rarely exceeding three hundred pounds per square inch, as to increase the unit pressure would produce rupture in the part of the arch subjected to tension. Concrete has the advantage that it can be reinforced with steel. With steel reinforcement, the mass of the masonry may be cut down fifty per cent. and the materials comprising the structure may be worked at predetermined and properly ascertained efficiencies.

As shown before, a concrete sewer will carry a much greater volume of sewage than a brick sewer of the same size, laid on the

same grade. Thus, when a given amount of sewage is to be carried, a smaller sized concrete sewer will suffice than would be required for a brick sewer. A concrete sewer six feet in diameter has nearly as great a carrying capacity as a brick sewer six and one-half feet in diameter.

Supposing in the two cases, the factors of thickness of the wall of the sewer, the cost of the material in each case to be the same, then the increased diameter will be responsible for an increase in the amount, and consequently in the cost of the material, of about five per cent., and for an increase in the amount of excavation necessary of about seven per cent.

From the above theoretical considerations we would suppose that brick sewers would probably be more expensive than concrete ones of the same carrying capacity. Upon examining cases where

Diam. of sewer in ft.	Length in ft.	Concrete Block Construction				Prices Bid Per Lineal Foot				
		Thickness in.	Vol. in cu. ft. p.l.f.	Transverse steel		Concrete Blocks	Monolithic Concrete		Brick	
				Size of rods	lbs. Total					
72	4342	5	8.4	9–16″	18.2	$17.70	8	$13.00	13	$12.75
66	2642	4½	7.0	7–16″	13.8	8.50	7	11.00	9	9.10
52	965	4	5.0	7–16″	10.5	6.25	6	7.00	9	6.85
48	980	4	4.76	3–8″	6.8	6.00	6	7.00	9	6.36
42	359	3½	3.65	3–8″	6.0	4.50	5½	6.00	9	5.76
36	321	3	2.68	3–8″	5.3	4.00	5½	6.00	9	5.00
30	714	2½	1.86	3–8″	4.5	3.00	4½	4.00	9	3.70
24	827	2½	1.50	5–16″	2.5	2.10	3½	2.50	9	2.20

TABLE No. 3.

bids have been received for the construction of a sewer of concrete or brick, we find that the truth of these assumptions is borne out by practice. A notable instance of this is a concrete sewer constructed at Toledo, Ohio. Bids were called for a sewer to be of either brick, concrete block, monolithic concrete, or reinforced concrete construction. The contract was awarded to Breymann and O'Neil, of Toledo, on block construction according to the designs and patents of W. C. Parmeley, C.E. The prices for each section of the sewer and for each different type of construction were as shown in the accompanying table, being the lowest one for each of the types. No bids were received for a reinforced concrete sewer.

Many cities have discontinued the use of brick in sewers on account of the heavy cost. Among these are Boston Mass., and Hamilton, Ont.

In the construction of the high level intercepting sewer in Toronto, certain sections of it were built of concrete lined with brick, and others of brick alone. In the sections where concrete

was used the economy was very marked as shown by the bids received for the two different types of construction. For instance, in Section No. 3 (Jarvis St. to the Don) the lowest bid received for a brick sewer was $33.13 per lineal foot, while for a concrete sewer the lowest bid was $19.97 per lineal foot. By the use of concrete alone a saving of $84,500 would have been effected in this section. As it was brick-lined concrete was used at a saving of $72,000 compared to the cost of a similar brick sewer.

The cost of concrete pipes varies greatly under differing conditions, but in general they are cheaper than vitrified tile pipes of the same size. At Denver, Col., seven thousand feet of 38-inch continuous concrete pipe was made by the Ransome process. The cost of the pipe was $1.35 to $1.50 per foot, with cement at $3.75 per barrel, gravel $1.25 per yard and wages $1.75 to $2.00 per day. The cost of the same size vitrified pipe would have been about $3.00 per foot in place.

In 1894 at Scarborough-on-the-Hudson 900 feet of 24-inch pipe and a mile of 10-inch pipe were built by the Chenoweth process at a cost of 95 cents per foot for the larger size and 23 cents for the smaller, as compared with 97 cents and 30 cents for the corresponding sizes of vitrified tile.

At Despatch, N.Y., concrete pipe made by the continuous process cost as follows; for 8-inch pipe about 6 1-3 cents per lineal foot, 300 feet being constructed per day, for 12-inch pipe, 10¼ cents per foot, about 400 feet being constructed per day. Vitrified pipe under the same circumstances would have cost 17½ cents per foot for the 8-inch and 35 cents per foot for the 12-inch pipe. As can be noted, these prices for the tile pipe are lower than they can be usually obtained at in most places.

The following table shows the thickness of cement pipe made by the Miracle Company with their estimate of the quantities and

Size inches	Thick-ness, in.	Cubic Feet of Sand per Pipe	Cost of Labor	Total Cost Per Foot
6	1	.324	$0.08	$0.050
8	1	.452	0.08	0.065
10	1⅜	.830	0.10	0.115
12	1½	1.100	0.10	0.155
15	1½	1.400	0.11	0.192
18	1⅝	1.840	0.13	0.237
20	1¾	1.950	0.13	0.255
24	2	2.750	0.15	0.343
30	2½	3.700	0.17	0.443
36	3	4.900	0.20	0.575

TABLE No. 4

cost. These figures were computed for a 1 : 3 mixture, and sand costing 75 cents per cubic yard and cement $2.00 per barrel.

The cost of cement and sand varies greatly in different localities, however $2.00 per barrel is a very common price for cement.

In general, concrete sewers seem to be cheaper than those of other materials, in many cases by a considerable amount, and very seldom, if ever, are they more expensive than those of brick or vitrified tile construction.

STEEL RAIL FAILURES

By H. Hyatt, B.A.Sc.

Part I.

The rail of rolled steel as it is used to-day in America for the carrying of railway traffic is a comparatively modern contrivance, although rail "ways" date back at least as far as the middle of the sixteenth century, when wooden planks, fastened end to end on logs of wood, were employed in the mineral districts of England as rails over which to pull wagons of coal from the mines to the waterways. In following the evolution of the rail, from this primitive structure as an origin, we find next that these wooden rails were covered with thin strips of iron in order to lengthen their serviceable life. This expedient caused excessive wear on the wooden wagon rollers, and led to iron wheels, which are recorded in 1734. With subsequent increase in traffic, however, the iron sheathing evidently did not prove of sufficient strength to carry the heavily loaded cars without buckling, and the plan was tried of making the rails of iron throughout. A lot of rails which were cast in 1767 were 3 feet long by 4 inches wide, and on the innerside was a perpendicular flange 3 inches high. These were laid flat, and are distinguished as Plate Rails.

The next important development was the Edge Rail, which was practically the plate rail set on edge, but was of necessity much stronger against bending. Subsequent developments were, the gradual but complete abandonment of the plate rail, increases in length, improvements in manufacture, and the substitution of wrought iron for cast iron, especially the latter, after an improved method of rolling was patented in 1820. Previous to this a species of socket joint had been tried, but, on account of frequent breakage, had been considered unsatisfactory and abandoned, and the joints were made in the cast iron chairs, which have since come into general use on English railways.

The advent and gradual development of the steam engine made possibilities of greater loads, longer hauls, and faster travel, and henceforth rails become of more importance than they had previously been.

In 1830 Stevens designed the tee rail, having a flat base, which was secured to the ties by hook-headed spikes without chairs, and which has since been the type of design employed in America. In 1837 Locke designed the double-headed rail,

which was an easily rolled rail, and, being reversible, was two rails in one. But as it was laid in cast iron chairs, the lower head was damaged by the hammering of the traffic, and was thus rendered useless as a running surface. Later the bull-headed rail was designed, in which the lower table was made of smaller size and to serve as a support only, not as a running surface. This rail became the basis of the rail which is now almost universally adopted in England.

Returning to the tee rail in America, we find that about 1857 the prevailing shape of rails was that which was known as the pear head (Fig. 1). This was the form of the cross-section of the wrought iron rail rolled by English mills for export—a cross-section adopted to prevent the sides of the head from breaking down. The wrought iron rail served its purpose as long as

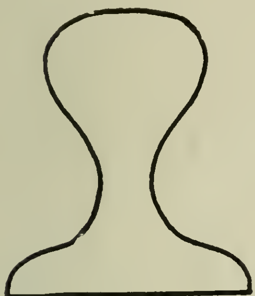


Figure 1.
84-lb. Wrought Iron Rail Section.
In use about 1857.

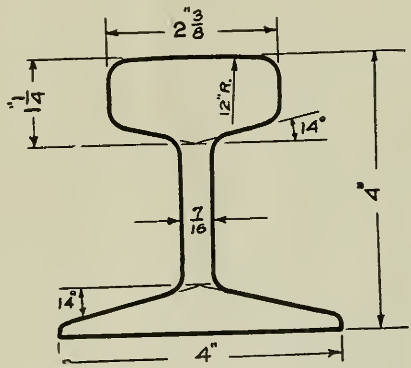


Figure 2.
53-lb. Steel Rail Section—Welch
Percentage of Area in
Head 45
Web 20
Base 35

wheel loads were not excessive nor speeds too high, but railroad progress seemed to have about reached its limit during the decade between 1860 and 1870. Further progress called for higher speeds and greater loads, but the wrought iron rails did not prove strong enough to withstand the weights imposed and the shocks incidental to high speeds.

In the meantime, however, Bessemer had discovered his process of steel manufacture, in 1858, and in the year 1867, at their Johnstown works, the Cambria Iron Company made the first commercial rolling of steel rails in America. These were rolled for the Pennsylvania Railroad Company from ingots made by the Pennsylvania Steel Co., at Steelton. This marks the beginning of the American steel rail, as it is employed at the present time. To quote Chas. B. Dudley from his presidential address to the American Society of Testing Materials, in 1908:

"Bessemer steel, the outgrowth of an attempt to make wrought iron cheaply, came just at a time when the wrought iron was beginning to demonstrate its unfitness to stand the pounding of the larger locomotives of the day. It is perhaps not too much to say that the Bessemer steel rail has made the modern railroad possible, and that without it or its equivalent, the world's development would be half a century behind its present advanced position."

The earliest steel rails very closely followed the sections previously designed for wrought iron, but Ashbel Welch, who later became a president of the American Society of Civil Engineers, made a radical departure from these when he designed his 53-pound section (Fig. 2). Rails of this section showed their advantage in that they outlived heavier steel rails of the older type, and also in economy of material. The Welch sec-

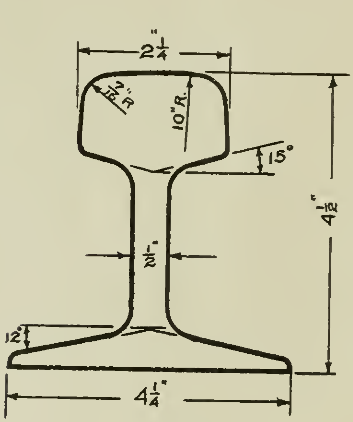


Figure 3.
Chanute Rail Section
Designed 1874
Percentage of Area in
Head 47
Web 20
Base 33

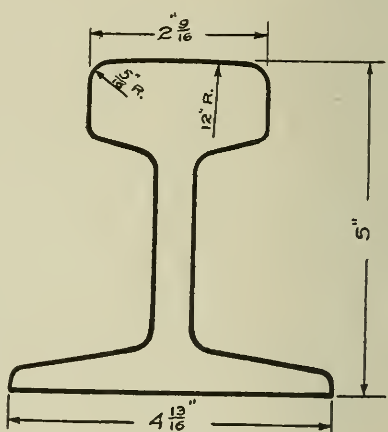


Figure 4.
80-lb. Rail Section—Dudley
Designed 1883
Percentage of Area in
Head 45
Web 20
Base 35

tion was used to a considerable extent, and for some years determined the type of rail used in America. But, in 1874, Chanute, then chief engineer of the Erie Railroad, brought out the section shown in Fig. 3. The essential departure from the Welch section is in the larger percentage of metal in the head, the straight flaring sides, and the thin web and flanges. The Chanute section became a basis for a number of other sections, sections with larger heads, particularly in the vertical dimension, with both perpendicular and inclined sides, with webs and flanges decreased in size for the purpose of getting metal into the head where the wear came.

But it became evident with experience that these rails with

the small webs and flanges and the heavy heads did not wear as well as the lighter rails rolled to the Welch section, and it was suspected by some that the fault lay in the design rather than in the chemical composition or the mill practice. A new and important departure from the then current practice was made in 1883 by P. H. Dudley, of the New York Central, who designed an 80-pound rail, which had a broad and shallow head in place of the narrow and deep head of the Chanute section (Fig. 4).

Since this period much has been said and done regarding steel rails. The year 1887 became the record year in both rail production and new track construction, about 13,000 miles of new track being built in the United States, and the production of steel rails amounting to over 2,300,000 tons, many of the larger systems became firmly established, problems of track maintenance began to receive more attention, and hence more attention was given to rails in an effort to make their employment as efficient as possible.

There have been a number of causes which have tended to complicate rail problems. The changes in the methods of transportation during the past twenty years, the increases in the sizes of both locomotives and cars, with the consequent increase in wheel loads, and in the strains produced, have made new demands upon railroad tracks, and especially upon the rail, as the most important element of the track. The average speed of trains has been largely increased; the average wheel loads of cars have increased 75 per cent.; and on some of the larger and more important railroads, the volume of traffic has increased at least 300 per cent., and perhaps more. The manner in which these changes have been met by increased weights per yard of rails, the modifications which have been effected in the Bessemer process of steel manufacture, the almost continual controversy which has existed between the steel manufacturers and the railroads, these and other items have all gone together to produce the modern steel rail problem.

Briefly stated, the problem is this: That, notwithstanding large and supposedly sufficient increases in the weight of rails, to correspond with the increases in traffic, speed, and wheel loads, the rails have not proved to be capable of carrying the traffic. In other words, the rails have failed, and their failure during service in the tracks is liable to be, and very frequently is, productive not only of serious financial loss to the railroad companies, but also of loss of life and serious injury to patrons and employees.

It might be supposed that with the advance of knowledge on the subject of rail design, and with the use of modern improvements in the art of steel manufacture, these failures would become less frequent as time went on. But for some reason or other this has not been the case.- We are not able to give a con tinuous series of figures to prove this conclusively, but the fol-

lowing paragraph, selected from many that are equally convincing, will remove doubt to a certain extent.

"The opinion is sometimes expressed that broken rails are not a cause of serious danger to trains. Any who may hold such an opinion will be interested to read the official report on railway accidents for the quarter ending September 30th, 1907. We there learn of a failure of a 100-pound rail, in service 9 years which cracked between the head of the rail and the web. Four passengers and one trainman were killed and 13 injured. Another case is recorded where a broken rail derailed a train running fifty miles per hour on a straight line, injuring thirty-two persons and doing $63,000 damage to the rolling stock. The break was due to an inferior defect in the rail. We can quote, however, statistics which are even more convincing than isolated cases. On October 1st last, J. Kruttschnitt, of the Committee on Standard Rail and Wheel Sections of the American Railway Association, in a report to the association said: 'Roads covering a mileage of 159,351 miles report 24,023 broken rails in 1905, and 28,478 in 1906, an increase of 18 per cent.; but in 1905 there were 4,576 breaks attributed to piping, while in 1906 there were 6379, an increase of 40 per cent in the breakages of piped rails. These breaks caused the death or injury of 65 persons in 1905 and of 339 in 1906, an increase of 420 per cent.' This is proof positive that broken rails do constitute a danger to the traveling public, and that piped rails causing inferior flaws are particularly dangerous."[1]

"Definite figures concerning rail fractures which seem to be the most extensive ever published, are given by the New York State Railroad Commission, in a bulletin issued a few days ago. They are contained in tables showing the total number of rail breaks that occurred on the principal steam railways in New York State during the winter months, January to March, inclusive, and showing how they are distributed as to size of rail and date of rolling. The totals show not only a surprisingly large number of fractures, but also a striking increase during the year just past, as exhibited in the following summary, which we have compiled from the commission's figures:"[2]

"No candid mind can view the present steel rail situation, and not be impressed with the thought, that the steel railroad rail, or, perhaps more comprehensively the railroad track of today, is called upon to justify itself in the eyes of the public. . . . . . . It is plain, we think, that modifications at some point, and possibly at many points, are essential, in order that the new conditions may be successfully met. The startling record of rail breakages, which has characterized the past two or three years, the rapid wear, and the almost appalling deterioration, due to the crushing and flattening of rails in track, have

1. Engineering News—V. 50—pp. 105.
2. Engineering News—V. 57—p p. 403

produced an outcry against the steel rail, which, seconded by the technical press, has culminated during the past two years, in a charge of criminal negligence on the part of those engaged in the manufacture of this great essential of railroad operation. No one at all conversant with the situation can maintain that the subject is not a pressing one, and I am sure that all will agree that there is necessity for calm, cool, and dispassionate consideration of the various elements involved in the problem."[1]

These few examples serve the purpose of showing the importance that is attributed to the subject by the technical press and those engineers and railroad officials directly concerned, and

SUMMARY OF RAIL FRACTURES ON THE PRINCIPAL STEAM RAILWAYS OF NEW YORK STATE, FOR JANUARY, FEBRUARY AND MARCH, 1905, 1906, AND 1907

NAME OF RAILWAY	Miles of Main Track in New York State*	1905		1906		1907	
		No. of Fractures	No. per Mile of Main Track	No. of Fractures	No. per Mile of Main Track	No. of Fractures	No. per Mile of Main Track
Delaware & Hudson.......	857	60	.07	60	.07	93	.11
Lehigh Valley............	807	125	.15	50	.06	103	.13
Rutland..................	171	10	.06	7	.04	20	.12
N.Y., N.H. & H...........	160	10	.06	2	.01	29	1.80
B. & M...................	146	34	.23	7	.05	5	.03
B. R. & T................	203	27	.13	4	.02	256	1.32
N.Y., O. & W.............	526	...	...	24	.05	.05	.02
Pennsylvania.............	332	140	.42	186	.56	205	62
Lake Shore..	158	227	1.44	34	.22	505	.32
N.Y.C. & H.R.............	4183	469	.16	288	.07	1244	.30
Erie.....................	1301	76‡	.06	142‡	.11	429‡	33
D.L. & W.................	630	153	.24	22	.03	115	18
Totals...............	9474	1331	0.14	826	0.09	3014	0.33

*Mileage from 1905 Report of State Railroad Commission.
‡Incomplete.

also gives a fair, although incomplete, idea of the number of failures which occur.

For the purposes of this paper the consideration of these failures can best be done by a classification of the causes to which they have been ascribed, and by a demonstration, chiefly through quoting various authorities, of their relative importance, together with some notes on the various remedies which have been proposed and adopted.

The causes to which rail failures have been attributed are

1. Chas. B. Dudley—Proc. A.S.T.M.—V. 8—pp. 19.

considerable in number, some authorities emphasizing one, some another, while others, and these are in the majority, consider that several causes have acted together to produce failure.

Classification is not in every respect advisable on account of the intimate relation existing between causes of two or more classes, but it is the only practical method of dealing with them, and hence we arrange them into four groups, as follows:

1. Design of the rail cross-section.
2. Chemical composition of the steel.
3. Manufacture of the steel and rolling of the rail.
4. Roadbed conditions and effects of the rolling stock.

Each group will be considered separately in the above order, as far as is practical.

Design of the Rail Cross-Section.

That the design of the cross-section of rails may be a factor, and an important one, in the abnormal number of breakages which have occurred, is not to be doubted, although, whether it actually is or not, is a much disputed question. There are, however, four ways in which it may enter into the problem. First, the section in use may be an essentially incorrect one, and unsuitable for the service for which it is intended. Second, the area and weight of the section may not be sufficiently great to withstand the wheel loads and other stress-producers that are present during service. Third, the section may be of such a form that the steel cannot be properly rolled. Fourth, the present section may be essentially correct in form, but nevertheless require improvements in its details.

With regard to the first item, namely, that the section in use may be essentially an incorrect one, there is not a great deal to be said. Comparison of the rail failure statistics of Great Britain with those of America will at once show that the advantage lies with Great Britain to a considerable extent. There is a possibility that this advantage is due to the different cross-section of rail in use. The bull-headed rail is a more simple section to roll and can therefore be better made. The similarity of the head and base produces a balanced rail, and the total absence of thin edges and of corners gives a section in which, during the process of rolling, the temperature may fall uniformly, thus doing away with a considerable portion of internal stress, and giving an opportunity to work the entire rail to a lower temperature. Such working produces a steel of finer structure and of a general soundness which cannot be had if the steel retains a large portion of its heat when working is concluded. But any proposition to adopt the British rail system in America must be considered an impractical one, even though it were conclusively proven that the bull-headed rail is superior to the tee rail. The question of cost will prohibit such a change for at least some years to come. Whether cost is the only consideration

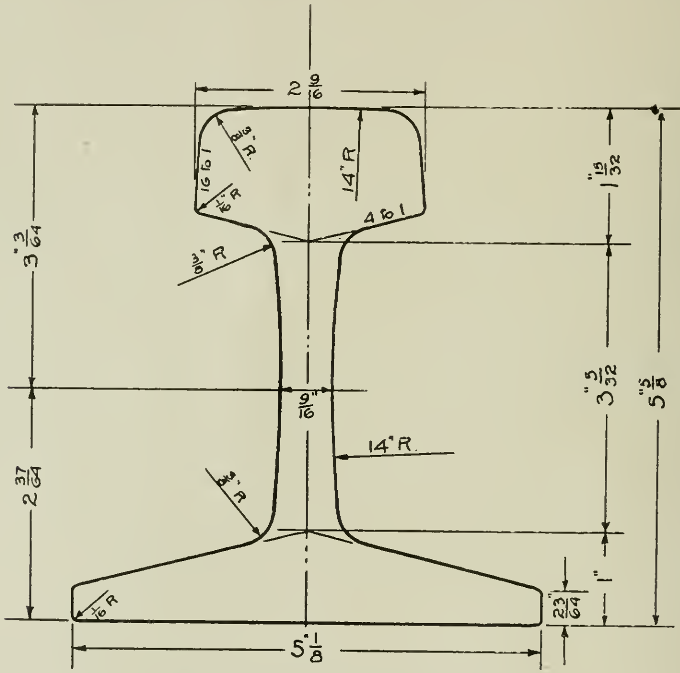
which prevents such a change of cross-section as this is a question which is rarely if ever discussed, authorities generally taking it for granted that improvement is to be sought in other directions. R. W. Hunt, during a discussion on the question of sections, in 1907, made the statement that, "We are now at a point where I think we ought first to make a radical departure in the design of the heavier sections." But what this radical departure was to be is not stated.

Concerning the second item mentioned, that the area and weight of the section may not be sufficiently great to withstand the wheel loads and other stress-producers that occur in service. Concerning this much has been said and written. The railroads maintain that the increase in the weight of the rail, that has been made to meet increases in the wheel loads, traffic and speed, have been all that is required, but the rail manufacturer maintains the contrary. There is room for argument on this question on account of the fact that it is extremely difficult to show as a matter of figures either one way or the other as to whether the steel is of sufficient area to withstand the stresses or not. It is doubtful whether the rail should be considered as a beam supported at each end or as a girder with three supports. It is doubtful as to the impact allowance which should be made, on account of the speed of the trains and also on account of a number of other shocks to which a rail is liable during the passage over it of a heavy locomotive, followed by a heavy train of cars. Under these conditions it is more a matter of opinion and experience than anything else as to whether the rails in present use are sufficiently heavy. It is known that locomotive and car weights have greatly increased, that traffic is much heavier now than a few years ago, and that speeds have also increased to a considerable extent. The question then remains, have the corresponding increases in rail weights been great enough? The only answer we can give is to offer the following opinions for consideration.

Regardin this question of increasing the cross-sectional area of rails, Chas B. Dudley, of the Pennsylvania Railroad, spoke thus: "Has the increase been sufficient? Is not a rail weighing 110, 120, or even 140 pounds essential to meet the strains produced by the changed conditions? Upon this point is possible to say that most careful studies have been made, using the best obtainable data, and making allowances for what is more or less unknown and uncertain, and that these studies indicate that the weight of rail, to carry the increased wheel loads, has been increased more rapidly than the wheel loads, and that the actual strain, with the heavier wheel loads, is no greater than was the case in the lighter rails under the lighter wheel loads formerly employed. It may be added that if 12,500 pounds per square inch is assumed as a safe working stress for such steel as rails are made of, the present 85 and 100-pound rail show stress well within this limit, even under a static wheel load of 30,000

pounds, with a dynamic augment of 60 per cent. of the static load. If these studies can be trusted, therefore, it would seem that so far as the weight of rail is concerned, the railroads have done all that could be reasonably required to meet the changed conditions with which we are dealing."

E. F. Kenney, of the Cambria Steel Company, is, on the contrary, directly opposed to this conclusion, as is evident from the following expression of his opinion: "With the coming of the extremely heavy wheel loads and the greater tonnage and speed which have been adopted in the last few years, the stress and



AMERICAN RAILWAY ASSOCIATION
90-lb. RAIL, SECTION "A"

Moment of Inertia—38.70	Total area 8.82 sq. in.
Section Modulus	Head 3.20 sq. in.—36.2 p.c.
of Head—12.56	Web 2.12 sq. in.—24.0 p.c.
of Base—15.23	Base 3.50 sq. in.—39.8 p.c.

shock in the rail have increased. Moreover, the difficulty of keeping up good track has increased, and since the condition of the roadbed as to line, surface, etc., has an immediate effect on the stresses and shock in the rail, these elements- combined with the direct effect on the rail from the increased loads and speed, have so increased the rail's work, that the factor of safety is about used up, and the great number of failures to-day shows that we are on the ragged edge. While the weight of the rails

has been increased from time to time, the increase has not, particularly in the past fifteen years, been in proportion to the increase of the loads, tonnage, and speed. . . . . In almost any engineering structure, an increase in the load and stress is met by the engineer by an increase in resistance, by means of greater sections and stronger members; but there seems to be very strong opposition to an increase in the amount of steel in the rail. . . . . . It seems quite probable that the adoption of much heavier rail sections than used to-day would be distinctly an economy because of the reduction of cost of maintaining the track. Aside from this it would be unquestionably an advance on the side of safety."

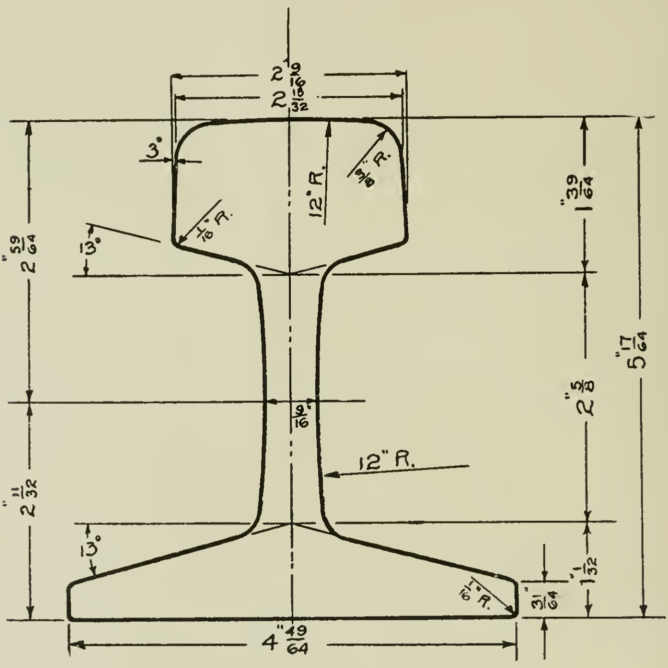
The rail committee of the Canadian Society of Civil Engineers, before the 1911 annual meeting of the society, reported concerning the question in part as follows: "The question has sometimes been asked, has the weight of the rail section increased as rapidly as the wheel loading? To this may be answered, Yes. In the days when a 60-pound rail section was a common standard an engine axle loading of 24,000 pounds was not infrequent; this loading produced a tension in the rail, under the conditions of column three of the table, of 13,440 pounds per square inch, as compared with 12,842 pounds per square inch for a 100-pound rail under an axle loading of 50,000 pounds." The conditions to which reference is made are a 100 per cent. allowance for impact and the consideration of the rail as a continuous girder resting on three ties, the central one of which is unstable.

The Rail Committee of the American Railway Engineering and Maintenance of Way Association in 1910 reported in part as follows: "The rail manufacturers have claimed that the heavy wheel loads might crush down the head by reason of overloading or overstressing the metal without the presence of any internal defect causing the failure. In the reports available every case of crushed head, when the rail was cut open, shows that it was accompanied by an internal defect, and it should have been classed as a split rather than a crushed head. It was supposed that a crushed head might be considered the fault of the railroad company, while the split head, full of seams and cavities, which we call pipes, would be clearly the fault of the manufacturer."

The third way in which the section may be a factor in the abnormal number of failures is that it may be of such a form that the steel cannot be properly rolled. That the form of the section is productive of a poorer steel than might with other sections be the case is a point which is granted by the greater number of writers on the subject. The difficulty lies in the uneven distribution of metal through the section. The depth and width of the head, as compared with the thickness of both the flange and the web are so much the greater that, during the process of rolling, the flange and web become cool and unrollable before the head, and hence when rolling is discontinued the

head of the rail is excessively hot. As is well known to every one acquainted with steel working, excessive temperature at the conclusion of rolling, is productive of a steel which is crystalline and generaly unsound, and, in addition to this, the variety of rates of cooling throughout the cross-section gives rise to a considerable amount of internal stress in the finished rail. The latest designs of rail call for an approximately equal percentage of metal in both head and flange, but the flange being wider than the head the same trouble continues, although perhaps in lesser degree. Concerning this portion of the subject we quote the following from Engineering, Vol. 84:

"High finishing temperatures are necessary, owing to the



AMERICAN RAILWAY ASSOCIATION
90-lb. RAIL, SECTION "B"

Moment of Inertia—32.30
Section Modulus
of Head—11.45
of Base —19.21

Total area 8.87 sq. in.
Head 3.56 sq. in.—40.1 p.c.
Web 1.70 sq. in.—19.2 p.c.
Base 3.61 sq. in.—40.7 p.c.

particular form of section of American rails. The heavy head, thin web, wide and thin base necessitate high finishing temperatures, otherwise it would be impossible to roll the bottom flange. This perhaps is the soundest of all the excuses advanced by the steel companies. The section should be of such form that the process of rolling and working of the material may be carried

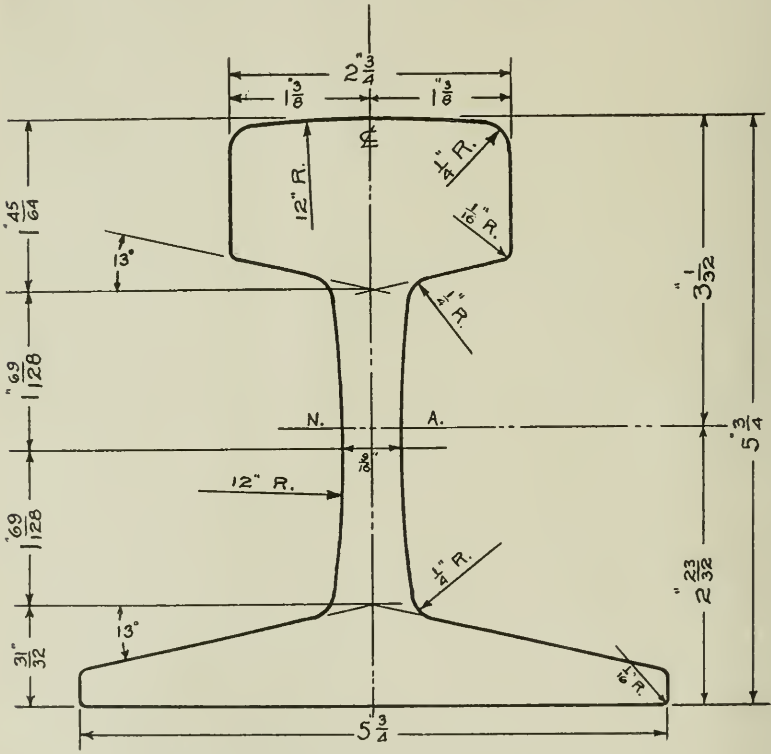
on in the manner best calculated to provide a good wearing rail."

W. R. Webster expresses the following opinion on the subject of the section with regard to rolling difficulties: "The sections now in use make it almost impossible to continue the work of rolling on the head to a low enough temperature to produce the fine-grained structure desired. . . . . The trouble is due to the large mass of metal in the head carrying the heat so much longer than the thin metal in the flanges, thus preventing the work of rolling on the head at sufficiently low temperature to break up the coarse grain and produce the tough, good-wearing rails desired. . . . . It has been the invariable experience in changing from a light to a heavy section, in any class of rolled steel, that difficulties have been made in the methods of rolling, in order to get as good structure in the heavier sections as was formerly obtained in the lighter sections. In ordinary sections, other than rails, it was a comparatively easy matter to overcome the trouble and get a good structure; but the thin flange of the rail, and the higher carbons called for in the heavier sections, further complicate matters. If a rail with the same width of head as the present American Society Civil Engineers' 100-pound rail is required, the head will have to be made thicker, and the radius under the head larger in order to prevent the sides of the head from shearing or breaking off as at present, and more metal put in the web and flange in order to carry the heat, thus allowing the head to be finished at the proper low temperature. This would mean a rail of about 120 pounds to 125 pounds per yard. I believe we are coming to heavier rails before we get rid of our present troubles."

There is not much doubt that the tee section in its present form presents difficulty in rolling. The difficulty can be overcome in some measure by placing as much of the metal in the base as in the head, and, since about 1885, when there was at least one section with 52 per cent. of the metal in the head as compared with 30 per cent. in the flanges, there has been a return to more of a balanced rail. Indeed the latest 85-pound section of the Canadian Pacific Railway has 41.02 per cent. of the metal in the base with 36.77 per cent. in the head, but this latter proportion was not so designed merely to overcome rolling difficulties. The balancing of the head and flange, however, is not the only thing that is required to simplify the rolling, as the thinness of the flange, as compared with the thickness of the head presents the same difficulty. This latter cannot be entirely overcome so long as the present form of section is employed. W. C. Cushing, chief engineer of the Pennsylvania Railroad, has not long since come to the conclusion, "That the new rail sections have not yet produced better quality of metal, where this has been sought by a better proportional distribution of material in head, web, and base, with a view to improving rolling conditions." And to the Rail Committee, who reported

to the American Railway Engineering and Maintenance of Way Association, in 1911, it seems "that the design of the rail section is not the main cure for poor material."

The fourth item is that the section in use may be essentially correct in general form, but requires improvements in its details. In addition to those details of the cross-section already considered there is one other, to which reference should be made in considering rail failures, and that is the size and shape of the rail head as considered apart from the overcoming of the rolling difficulties. In designing the head of the rail there are two other items to be considered besides rolling difficulties, and they are,



AMERICAN SOCIETY OF CIVIL ENGINEERS
100-lb. RAIL SECTION

Moment of Inertia—43.80
Section Modulus
of Head—14.85
of Base—15.64

Total area—9.82 sq. in.
Head 4.13 sq. in.—42 p.c.
Web 2.06 sq. in.—21 p.c.
Base 3.63 sq. in.—37 p.c.

first, the strength of the rail as a girder for the sustaining of the wheel loads, and, second, the quantity of metal that is available in the vicinity of that part of the section where all the actual wear comes during service in track.

In those cases where the girder action of the rail is assumed to be the more important the rail head has been made wide and shallow, whereas in those cases where the wear of the rail by the wheel treads is considered the more important the head is made narrow and deep. Both varieties of section are in common use, but the majority of writers favor the deep-headed rail. The case appears to be well represented by E. F. Kenny in the following words: "The desirability of stiff track is so well known and understood that some of the engineers working on the problem have shown a disposition to get the extreme value of stiffness that is possible with the amount of metal they are willing to use. This unquestionably makes better riding track and reduces the cost of maintenance, but they seem to forget in this hunt for stiffness that in disposing their metal so as to get the maximum moment of inertia, they are crippling the section in its details. Now, over 90 per cent. of the rails which fail do not fail as girders, but in their details; the split heads and broken bases are in no case the result of girder action. Regarding the split head, which is the type of failure probably causing more trouble than all the others combined, the following may be instructive: . . . . Road A uses a deep-headed rail, while B and C use a shallow-headed rail. The number of 100-pound rails removed from track in one year per 1,000 tons rolled is 0.66 for road A, and 12.59 for road C. The number of 85-pound rails removed from track in one year per 1,000 tons rolled is 0.59 for road A, 6.02 for road B, and 8.08 for road C. . . . . . Of the failures on the last named roads 90 per cent. were in the head, i.e., splitting, often spoken of as piping, while this type of failure was almost unknown on road A, with the deep headed rail. The shallow head is an element of weakness, which must be avoided if we are to escape this type of failure, and the necessary stiffness should be provided, not by spreading the metal out so thin as to weaken the head and base of the rail, but by the addition of enough metal to furnish the required girder strength without weakening the section in its details."

Ed. Note.—The second part of this article, dealing with roadbed conditions, rolling of steel, and chemical composition, will appear in the July issue.

The frequency with which some of our graduates' names appear has attracted the eye of a School man, who takes live and consistent interest in School affairs. He calls to our attention the fact that in the latest addition of the calendar the name Johnston appears fourteen times in the list of graduates. The name Campbell has thirteen adherents. There are twelve Smiths, twelve Browns, ten Wilsons, nine Stewarts, eight Rosses, and seven each by the name of Young, Robertson and Moore.

BIOGRAPHY

Mr. G. H. Duggan

One of the three men who comprised the graduating class of 1883 is Mr. G. H. Duggan, of Montreal. Born in Toronto in September, '62, instructed in Upper Canada College, from which he matriculated in 1879, Mr. Duggan entered the School of Practical Science in Engineering, the only then existing course, in 1880. The calendars of '81, '82 and '83 record Mr. Duggan's name as the winner of the first prize in Engineering in his first, second and graduating years respectively. It may be stated for the information of younger graduates that the course then comprised only three years.

For the session '83 and '84 Mr. Duggan was a member of the teaching staff of the School as Fellow in Engineering. Leaving the institution early in '84, he engaged as topographer on location, Mountain Division of the Canadian Pacific Railway, at Kicking Horse Pass, and later in the year he was in the designing office of the Canadian Pacific Railway at construction headquarters. In 1885 he was in charge of brick work in Field, Selkirk Range, and later of grading the summit of Gold Range, of the same mountain division.

While with the Canadian Pacific Railway he was connected with the construction of all large wooden bridges on Kicking Horse Division, the east slope of Selkirks, including Stoney, Surprise, Mountain and Raspberry Creeks, and the two crossings of the Columbia River.

Severing his connection with the Canadian Pacific Railway, in December, 1885, he engaged with the Dominion Bridge Co., first as draftsman, two years later as chief draftsman, and in 1891 as chief engineer, retaining the latter position for eleven years, during which connection with that company most of the important structures built by them were constructed, including the St. Lawrence River bridges at Lachine, Coteau and Montreal; the Interprovincial at Ottawa; bridges at Sault Ste. Marie, Grand Narrows, Fredericton, Bout de L'Ile; the hydraulic lift lock at Peterboro; the movable dam and regulating gates at Sault Ste. Marie, and other structures aggregating about 400,000 tons.

In February, 1902, Mr. Duggan engaged with the Dominion Iron and Steel Company and the Dominion Coal Company, as assistant to president on construction. In 1903 he was appointed third vice-president of these organizations. From 1904 until February of 1910 he was second vice-president and general manager of the Dominion Coal Co. Much of the development work was carried out under his direction, including the surface plants at mines Nos. 2, 3, 5, 6, 7, 9, 10, 12, 14, and 15; the unloading plants at St. John, Quebec, Three Rivers, and Montreal; and its machine shops, railway branches, shops, etc.

The Dominion Bridge Co. acquired his services at the beginning of 1910, as its second vice-president and chief engineer, which position he holds at present. He is chief engineer of the St. Lawrence Bridge Co., contractors for the superstructure of the new Quebec Bridge.

The busy professional career briefly outlined in the foregoing fails to mention Mr. Duggan as president of the Engineering Alumni of the School of Practical Science, in 1894. He became associate member of the Canadian Society of Civil Engineers in 1888, and member in 1890. He was a member of its council during the years '94, '96, '98, '99, '04, '07 and '12. He was vice-president of the society in '97, 1900, '01, '02, '03 and '08. He is also a member of the Institution of Civil Engineers, of the American Society of Civil Engineers, and of the Canadian Mining Institute. He was vice-president of the Institute in '04, and is this year a member of its council.

The Engineering Society has always had a constant supporter and enthusiast in G. H. Duggan, '83. Last year the society put forth special efforts to have him attend their annual dinner, and were at the point of success when unforeseen business necessitated his remaining away. It was a great disappointment to the executive, but its statement has been endorsed by the new executive, that Mr. Duggan should be a guest and a speaker at the School dinner this year.

SCHOLARSHIPS

Among the applications for research scholarships in the Faculty of Applied Science that have been received by the Engineering Alumni Association none deal with any of the following problems:

First, Materials for Roadway Building.
Second, The Flow of Air in Pipes.
Third, The Properties of Masonry.
Fourth, The Design of Concrete Pipes.

These being subjects upon which no advanced research work has been done, and concerning which there is a great deal of important information lacking at the present time, the scholarship committee is disappointed that no applicant up to the present time has made any of them the basis of his request for research privileges. Some of the applications that have been received deal with problems of almost equal importance, and many of them appear as though they would lend themselves to profitable research. Several of those mentioned above, however, are in urgent need of investigation, and if any graduate has been contemplating applying for a scholarship on one of these or similar topic we feel sure that further study on his part of conditions as they at present exist, will convince hi mthat the time is opportune for active investigation.

LETTER TO THE EDITOR

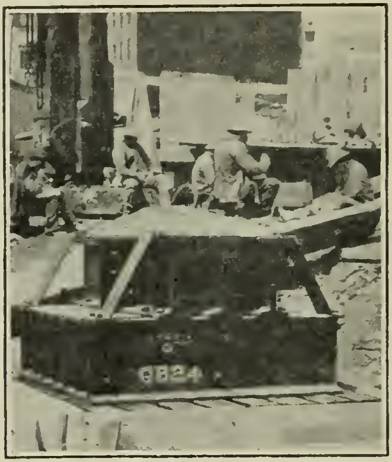
A UNIQUE COLUMN FOOTING CONSTRUCTION

Dear Sir:—

I enclose you herewith drawings and photos showing a design for a column base, adapted for use in building construction, made entirely of rolled shapes, which I have been using in my practice for a number of years, and which may prove of interest to the readers of APPLIED SCIENCE.

The beams are bolted up complete in the shop, including separators, and the top and bottom layer of beams likewise are bolted together, all ready for erection in one piece. The advantages over the conventional cast iron base are as follows:—

(1) In comparison with cast steel, it is both cheaper and more reliable. In my own experience, I have had cast steel bases develop



After Being Set.

cracks after having been erected, although they had been carefully annealed and inspected before leaving the shop. These had to be replaced after several stories of steel work had been erected, which entailed very considerable expense.

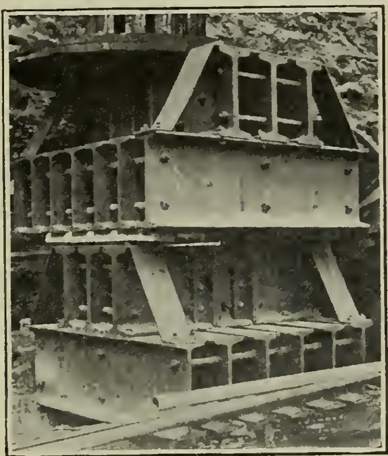
(2) In comparison with cast iron, it is as cheap and very much more reliable. In an experience extending over many years in the use of cast iron bases, I have known far too many to have developed cracks after they had been erected in the building, often entailing large expense for replacing them. For this reason I have not been using cast iron bases for the last ten years.

(3) This form of base is easier to set properly, being much more readily grouted.

(4) Stresses can be readily calculated (which cannot be said of the usual design of cast base), the conventional method of analysis

for shear, crippling and bending being accurate enough for all practical purposes.

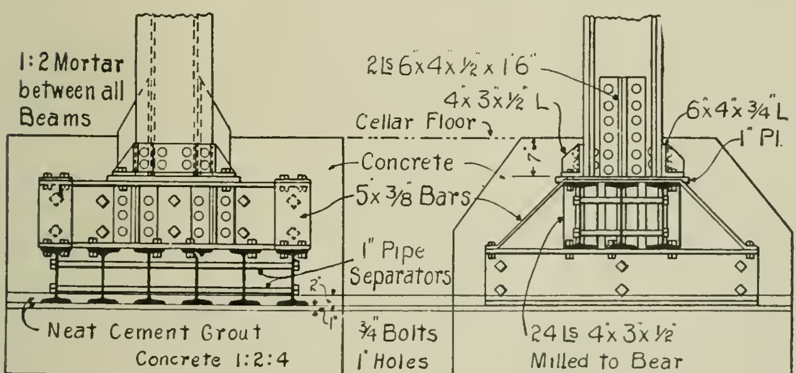
I have used the design as shown in the prints for loads up to 1,600 tons, and by slight modifications in details it may be used for



Stacked Up Ready for Shipping.

much larger loads. My preference is for shallow beams with heavy webs. If deep beams are used, webs may very likely have to be reinforced against crippling. In the top layer of the beams, I always use stiffeners ground to fit tight between the flanges to prevent crippling of the web of the beam, whether the calculations require them or not.

There should be plenty of pipe separators between the beams



Typical Column Footing with Square Base.

and in the top layer these should not be over six inches on center vertically and eight inches horizontally.

The space between beams is filled with a rich Portland cement mortar consisting of one part cement to two sand, to prevent corrosion in case the foundation is wet.

This type of base permits the use of a very simple detail at the bottom of the column.

Yours very truly,

E. W. STERN.

New York City, N.Y., May 14th, 1912.

NEW MEMBERS OF THE BOARD OF GOVERNORS

Mr. T. A. Russell and Lieut.-Col. A. E. Gooderham have been appointed by the Provincial Government to places on the Board of Governors of the University of Toronto, and will occupy the chairs previously occupied by Hon. W. T. White and Hon. T. W. Cruthers.

PROFESSOR MILLER IS PRESIDENT

Professor W. Lash Miller, of the Department of Chemistry, is president of the American Electrochemical Society, as a result of a recent appointment. Professor Miller will represent the society at the Congress of Applied Chemistry, which meets in Washington next September on the invitation of the President of the United States. This will be the first time the society has met in America, the last meeting, five years ago, having been held in Rome.

SOCIETY OF CHEMICAL INDUSTRY

The executive of the Society of Chemical Industry for 1912 and 1913 is made up as follows: Chairman, Wallace P. Cohoe; vice-chairmen, R. F. Ruttan, W. L. Goodwin, and Prof. J. Watson Bain; executive committee, H. P. Mills, O. H. Wurster, R. T. Mohan, of Hamilton; A. Neighorn, Milton; L. Hersey, C. F. Heebner, J. A. De Cew, Prof. W. Lash Miller, G. F. Guttman, N. N. Evans, T. H. Wardleworth, E. G. R. Ardagh.

The article on "Stereographic Measurement," in the May issue, is one of several articles on this subject appearing in the Canadian Engineer during the summer. Professor Anderson will give further information and examples concerning the stereo-comparator and its uses in his next article.

E. Andrews, '97, of Maen Offeren Slate Quarry Co., of Portmadoc, North Wales, was a visitor in the city recently with the British Manufacturers' Association. Mr. Andrews paid a visit to the School during his short stay in the city.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published every month in the year by the University of Toronto Engineering Society

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Per year, in advance	$2.00
Single copies	20

Advertising rates on application

Address all communications:

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Engineering Bldg., University of Toronto,
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EDITORIAL

As a direct result of the return to this office of subscription orders sent out in March, we have been able to reduce our monthly expense of mailing "Applied Science" to less than half its previous amount. This saving could not be effected in any other way. It is but a beginning. As soon as a reasonable number of further subscription orders are received we will again approach the Post Office Department at Ottawa for postal privileges upon them also, and we have the assurance that our request will receive consideration.

THE MATTER OF POSTAGE

The motive behind the idea is this: Our subscription price to graduates is one dollar per year. This does not defray the expense that twelve copies of "Applied Science" incurs. These copies cost a little over ten cents each to print and prepare for mailing. Thirty-six cents at least must, under the old rate, be

added to this for postage. If we hold in this office a request, by post card or otherwise, that a person wishes to receive "Applied Science" throughout the year, and will send us one dollar for it later on, that advice will entitle us to a rate whereby his twelve copies will cost us, not thirty-six cents, but one and one-eighth cents to mail. The receipt of five hundred more of these orders will mean a further yearly saving of nearly $175.00 in postage. Will the graduates consider what this means to "Applied Science"? Drop us a letter or post card, and we will soon be able to show its meaning in actual figures.

Every graduate should and most graduates will send us the subscription price of the Journal. We must hasten to state that this is not a solicitation of dollars. The important point is that reduced postal privileges apply only to those on our mailing list who authorize us in some manner to mail the Journal to them, and then only for such a length of time as they mention in their advice.

If the previous subscription blank is at hand you will confer a great favor by using it: if not, a letter or post card will assist just as materially. The dollar subscription means a great deal to "Applied Science" when it reaches us, but it may attain an increased value of 35 p.c. if it is paid, or undertaken to be paid, at the beginning of the year of issue to which it applies.

Just now we are trying to secure subscription orders on copies to January, 1913. One-half of the copies which the order is to cover have already been received. The sooner we receive subscription orders the more value they are to us in this campaign. We will waste no time, on our part, in putting them to their desired use relative to postal rates.

EMPLOYMENT

Neither now nor at any time during the last month have we been able to fill the applications for men that have come in from companies engaged in various branches of engineering. At the time of writing we can supply about fifteen civils and six electricals or mechanicals with positions at very acceptable salaries. Such as this has been the condition of affairs since early in the month of May. It would be a very satisfactory state, providing all our men were satisfactorily employed, but we feel safe in saying that there is quite a number of undergraduates who should be at practical work during as much of the summer vacation as possible, and perchance there are a few graduates who would be deeply interested in the number and nature of applications for positions that are on file.

When, as is very often the case, a request is received, asking that a man capable of running a level or handling a party, let us say, be sent without delay to a place where his services are immediately required, it is necessary for us to act accordingly; and unless there is in our office a corresponding request from a

man seeking employment of that nature it is extremely difficult to fill the vacancy. The remedy is in the interest of the School man and is likewise in his power. If every man who receives "Applied Science" would keep us informed throughout the time he is idle, by writing us from time to time, we would then be in a position to place him as soon as an application for such a man is received. This does not necessarily mean daily reminders or anything of that nature, but obviously a man might secure a position by other means, not inform us of it, and allow his name to remain on our list, perhaps preventing another of our men securing a position reserved by us for the first man.

There have been a number of cases, this year and last, where a man followed up prospective positions obtained at this office, but did not inform us whether he met with success or otherwise. His name remains upon our "Positions wanted" list, and the position which he succeeded in securing is also open, according to our list, for other men seeking employment to needlessly apply. By informing us as to whether or not he secured a position this deficiency would be eliminated, and no already-filled prospects need bother the man who is in search of a job.

THE SCHOLARSHIP IN MECHANICAL ENGINEERING

The scholarship offered at the beginning of last year by the Boiler Inspection and Insurance Company of this city, was won by Mr. A. S. Anderson, '13, for proficiency at the recent examinations. The scholarship is to the amount of $130.00, and is awarded to the candidate who takes the highest standing in Mechanical Engineering in the third year.

J. B. Challies, '04, has been appointed superintendent of the new water power branch of the Department of the Interior. This new organization will make surveys of Canada's water powers, and will gather data on stream fall.

E. W. Richards, '99, who has for some time been in charge of the stores and purchasing department of the Toronto Hydro-Electric System, has been appointed to the position of appraiser in the Customs Department of the Dominion Government, at Ottawa.

J. C. Gardner, '03, has been appointed to the position of chief engineer on the construction of the Good Roads of Welland County. Mr. Gardner is to establish a system of road maintenance and supervision, and is building one hundred and fifty miles of roads this season, at an expenditure of $400,000.

A. P. Linton, '06, until recently with the St. Lawrence Bridge Co., Montreal, has accepted an appointment with the Department of Public Works, Regina, as assistant Chief Engineer of Public Works in the Province of Saskatchewan.

WHAT OUR GRADUATES ARE DOING

E. R. Smithrim, '07, is engineer for the Watrous Electric Light, Power and Traction Co., Watrous, Sask.

R. S. Houston, '06, is employed by the Vulcan Iron Works Co., Winnipeg, Man.

W. R. Carson, '05, is chemical engineer for the Grasselli Chemical Co. of Cleveland, Ohio.

E. Wade, '04, is carrying on a contracting and building business at Welland, Ont.

J. L. Allan, '00, is assistant engineer construction department, Intercolonial Ry., Dartmouth, N.S.

Wm. L. Lawson, '93, is manager of the Great Western Sugar Refineries in Colorado.

C. F. Hanning, '89, is divisional engineer for the C.N.R., and is located at present at St. Eustache, Two Mountains, P.Q.

C. G. Townsend, '04, and J. M. Wilson, '08, of the firm of Wilson, Townsend & Saunders, contracting engineers, have their headquarters at Moose Jaw, Sask.

Ed. Harrison, '06, and G. M. Ponton, '09, are engaged in civil and mining engineering and land surveying, with offices in the Beveridge Building, Calgary, Alta.

D. D. MacLeod, '10, is engaged on hydrographic work for the Department of the Interior, at Calgary.

Wm. A. O'Flynn, '10, is in the chemical laboratories of the Copper Queen Smelter, at Douglas, Arizona.

R. B. Chandler, '11, has recently been appointed Assistant City Engineer of Saskatoon, Sask.

"Jeff" Taylor, '04, is stroke on the Argonaut eight that left recently to compete at the Henley regatta, and in Sweden.

J. Lanning, '11, a contributor in the May issue of "Applied Science," is with the Geological Survey of Canada. After having spent a month on work near St. John, N.B., his party left recently for Athelmar, B.C.

J. W. Tyrell, '83, is spending the summer in Europe, and will return about September.

R. G. Sneath, '11, is in charge of sewer and water works installation at Melfort, Saskatchewan, for McArthur & Underwood, of Saskatoon.

P. G. Cherry, '11, is manager of the circulation department of the "Canadian Engineer," Toronto.

E. O. Fuce, '03, has just resigned his position as engineer of the Municipality of Galt, to begin private practice in Calgary.

Mr. W. A. Hare, '99, president of the Hare Engineering Co., of Toronto, is on a business trip to Europe, and will be away for about six weeks.

A. B. Mitchell, '08, sailed recently for England as a member of the Canadian Bisley team, to compete in the July meet. Mr. Mitchell has just returned from Harvard, where he has been receiving special instruction in architecture.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 24 TORONTO, JULY, 1912 New Series Vol. VI, No. 3

TRANSPORTER BRIDGES

By Henry Grattan Tyrrell, C.E.

Transporter bridges of one kind or another have been in use for many centuries. The earliest ones are probably those of India, called by the natives "tarabita," and used by them for crossing streams or mountain gorges. They consisted of a single rope made of hides or fibres fastened at the ends to trees on shore, and from this rope a basket was suspended and drawn back and forth by a smaller cord. Similar bridges are known to have been used many centuries ago by the natives of Peru and adjoining countries in South America.

A contrivance of this kind, though with more detail, was used by Faustus Verautius about 1620. Wooden posts or towers were planted at each side of the stream, and between the tops of the posts was stretched a rope or cable from which a basket or car was suspended by two trolleys, one attached to each end of the conveyor. Landing platforms or brackets were fastened to the towers at the proper elevation to correspond with the floor of the moving car, and these platforms were reached by wooden ladders from the ground. A smaller endless hauling rope passing over a pulley on the top of each tower, hung loosely in the car, and by means of this rope, the car and its load was drawn back and forth by one of the occupants. These early inventions are the prototypes of the more elaborate modern cableways and transporter or ferry bridges.

The principles contained in the primitive bridges described above, were revived in England during the first part of the nineteenth century, when patents were granted to Smart, Fisher & Leach for three different types of railroad drawbridges. Drawings and models were made in 1822 for Smart's bridge, and Fisher's patent for an aerial ferry was taken out two years later, but more elaborate drawing, though somewhat similar to Smart's, was that proposed by Harvey Leach for a suspension railway ferry. His plan showed a series of spans 300 to 400 feet in length, above which cables were suspended which supported a horizontal track or runway high enough above water to leave the desired head room below, for ships and river craft. From the upper runway, a platform the full length of one span was suspended between the piers, and this platform, with its load, was capable of being moved back and forth as desired.

A patent for an aerial railway bridge to cross the East River at New York was granted about 1852 to H. N. Houghton, of Bergen, N.J., who proposed placing a number of heavy stone piers in the river, with truss spans thereon, and a clearance under the spans of 150 to 200 feet for ships. Instead of expensive approaches to a high level bridge, he proposed suspending a moving platform for a double line of railway, and making this platform long enough to carry whole trains of cars. The obstruction which this plan offered to shipping was from the river piers only, the space between them

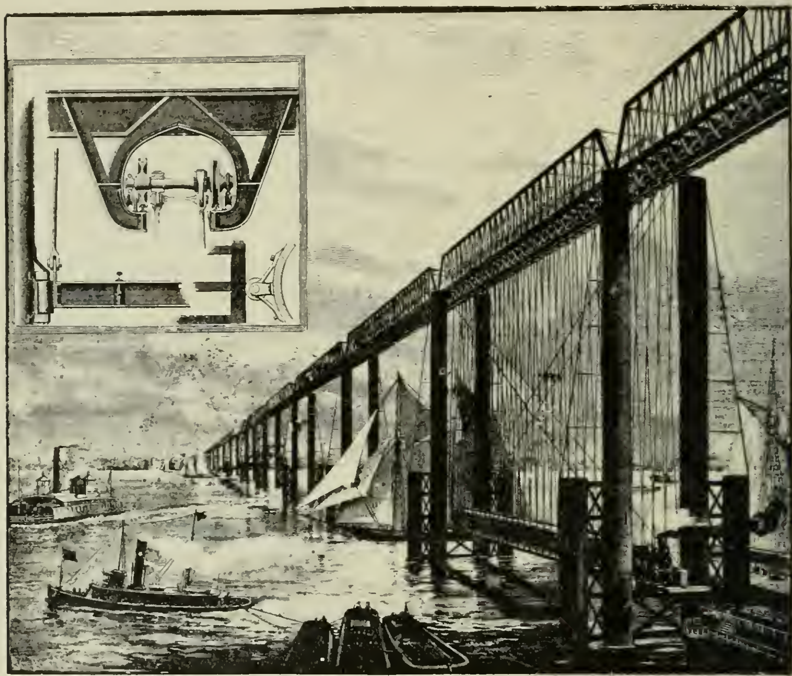

Fig. 1.

being always open except for the occasional passing of the moving platform. To avoid all river obstruction, even that offered by the piers, it was proposed by Morse in 1869 to cross the East River with a single suspension span having a clear opening of 1,410 feet and an under height of 140 feet, travel being conveyed, not over the bridge, but on a moving platform suspended from the upper runway deck. In other respects his design was similar to Houghton's. for it showed no inclined approaches, but merely a suspended platform about 150 feet long to travel back and forth at intervals between New York and Brooklyn. As far as the length of span was concerned, the design was not remarkable, for suspension bridges with lengths of 1,200 feet or more between the towers, had previously been built, and several had been proposed of much greater length,

including the notable design of M. Oudry, for crossing Messina Straits with four suspension spans of 1,000 meters each.

In 1873, Mr. Charles Smith, manager of the Hartlepool Iron Works, of Hartlepool, England, designed a transporter bridge with cantilever trusses to cross the Tees at Middlesborough, with a center span of 650 feet and a total length of 1,000 feet. His plans were endorsed by no less an authority than Benjamin Baker, but because of insufficient funds, the project was not carried to completion and a steam ferry was installed instead, at a cost of less than $50,000. On account of the publicity given to this project, it has often, but incorrectly, been referred to as the first design for a transporter bridge.

Five years later, an elaborate plan for a transporter bridge over the Thames, was prepared by L. Mills and A. Twyman of North Shields, with a center opening 200 feet in width and 80 feet high. The upper platform, reached by elevators in the towers, was to have provision for pedestrian travel, so that foot passengers could cross at all times.

As transporter bridges are especially suitable for crossing harbor entrances at the sea coast, the type had for many years been advocated for the water sources at New York, and in 1885, Mr. John F. Anderson published a design, Fig. 1, for crossing the Hudson by means of a moving platform suspended from a high level track, supported on pairs of cylinder piers. The platform was to be long enough to always be in contact with three sets of piers, thereby insuring lateral stability. In other respects the design was quite similar to those previously prepared by Harvey Leach and H. N. Houghton, and to Haege's plan for a rolling railway bridge. Two years previous to this (1883), Mr. Gustav Lindenthal had been granted an American patent on a transporter bridge with a traveling suspended car.

During the year 1894, two important passenger cableways were erected, one near Knoxville, Tennessee, and the other at Brighton Dyke, England, the car on the former one moving on a cable with steep incline. The cableway crossing Devil's Dyke at Brighton, designed by W. J. Brewer, had a clear center span of 650 feet, the type being selected because conditions would not permit the expense of a regular bridge. An upper unstiffened cable over the towers, with a sag of only 26 feet, supports all the load, and two lower horizontal cables suspended therefrom by one-inch steel bars, carry the trolley at a height of 230 feet above the valley at the deepest part. The car is only 5 by 7 feet, to hold from eight to twelve passengers, and it is hauled back and forth by a smaller rope, making the passage in 2½ minutes. After its completion, 720 people were taken across and back in 2½ hours.

The development and introduction of transporter bridges is due chiefly to the enterprise of Ferdinand J. Arnodin, proprietor of the iron works at Chateauneuf, France, who during the past twenty years has erected at least eight of these structures at Bilbao, Bizerta, Rouen, Rochefort, Nantes, Marseilles, Newport, and

Tangier. The first of these, between Portugalete and Los Arenas, over the mouth of the Nervion or Bilbao River, on the coast of the Bay of Biscay, about ten miles from Bilbao, Spain, was completed in 1893 (Fig. 2). The metal towers rising at each side of the river are 525 feet apart on center, and a horizontal runway 131 feet above water is supported by cables passing over the towers and anchored to blocks of masonry. The horizontal runway, in addition to hanging from the cables above it, is supported at each end for about one-quarter the span length, by stay cables from the towers. The total moving dead load is 40 tons, and the car which carries 150

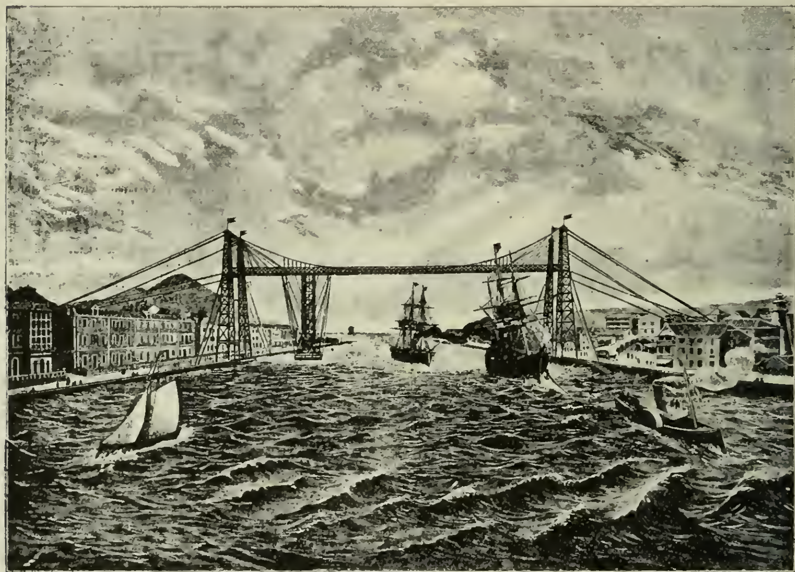

Fig. 2.

passengers, crosses from one side to the other in one minute. The design is the combined work of Arnodin and Palacio.

The second of M. Arnodin's designs crosses a canal at Bizerta in Tunis, and replaced the ferry which was guided by a cable during transit. The bridge was commenced in 1896 and completed two years later. It is similar in outline to that at Bilbao but with a shorter span, the distance between the towers, which are 213 feet high, being only 355 feet, though the under clearance of 148 feet is slightly greater than the previous one. The car is 32 feet by 24 feet, and it is moved by a steel cable and steam power. The itemized cost was as follows:—

Steel, without machinery	\$95,500
Machinery	8,600

Miscellaneous work	2,600
Duty	5,000
	$111,700

It was severely tested by a cyclone in 1898, but remained uninjured. It was proposed by the government in 1904 to take the structure down and to re-erect it at Bordeaux or Brest, changing the motive power from steam to electricity.

The third of M. Arnodin's designs was completed a year later (1899) over the Seine at Rouen, being quite similar to his first one at Bilbao, though with a larger capacity and cost. The clear distance between docks is 436 feet, and between tower centers 469 feet, while

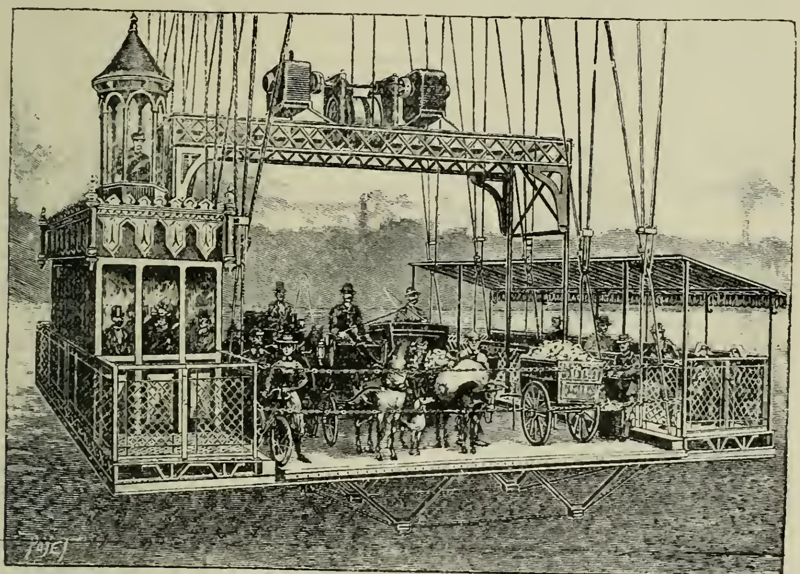

Fig. 3

the under clearance above the dock is 164 feet. The towers, which are 221 feet high, support twelve steel wire cables from which the horizontal runway is suspended. The moving platform is 33 feet long and 42 feet wide, and has a weight of 37 tons when empty, and 45 tons when loaded. It has a capacity for 200 persons and 6 vehicles, and is suspended from the trolley by thirty cables. The car, Fig. 3, can be made to cross the channel in 45 seconds, though the usual time is about 80 seconds. Its maximum daily service is 240 trips to and fro, carrying 300 vehicles and 10,000 passengers. It cost $180,000 and the schedule of tolls thereon is as follows:—

First-class passengers	2 cents
Second-class passengers	1 cent

Two wheeled rig	6 cents
Four wheeled rig	8 cents
One-horse cart, empty	5 cents
One-horse cart, loaded	8 cents
Two-horse cart, empty	7 cents
Four-horse cart, loaded	13 cents

During the following year (1900), M. Arnodin proposed several transporter bridges in England, one over the Ribble Navigation, and another over the Tyne between North and South Shields, with a span of 650 feet, having the co-operation of Mr. C. H. Gadsby on the latter one. In June, 1901, M. Arnodin took out American patents on a transporter bridge of cantilever type with suspended center span, similar to that which he completed in 1903 over the Loire River at Nantes, which was the first of its kind to be completed. The platform of the bridge at Nantes is supported at intervals of 15 feet by stay cables from the tower tops, and the projecting cantilever arms are connected by a suspended span 113½ feet long. The front and rear arms of the cantilever are 175 and 82 feet long respectively, and the rear end is tied down with wire ropes to the anchor masonry. The distance between the tower centers is 462

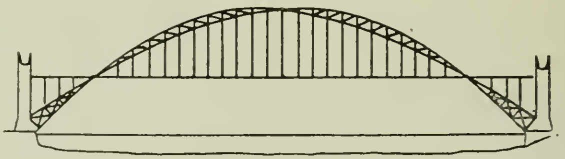

Fig. 4

feet and the total length 626 feet, the clear height underneath for ships being 165 feet. The trusses are 26 feet apart and the car suspended from them is 40 by 40 feet, with a maximum capacity of 60 tons. It is operated by an electric motor on the truck, and will cross the water in one minute. It cost $199,000, and the schedule of charges is as follows:—

Pedestrians	1 cent each
One-horse cart, empty	5 cents each
Two-horse cart, empty	7 cents each
One-horse cart, loaded	8 cents each
Two-horse cart, loaded	10 cents each
Wagons, loaded	12 cents each

The most daring project for a transporter bridge ever undertaken was that which appeared in 1903 for crossing the Gironde River at Bordeaux, with a single arch of 1,412 feet (Fig. 4) the span being about the same as that designed by Morse in 1869 for crossing the East River at New York. The proposed Bordeaux bridge consisted of a pair of metal arches, in vertical planes and about 80 feet apart, from which the runway deck was suspended, leaving a clearance of

150 feet beneath it. The total rise of the arch was 328 feet (100 meters) and that part of the ribs above the runway were lune-shaped with three hinges, the longitudinal distance between the end pins being shortened by this arrangement to 990 feet, similar to that used about the same time for the Austerlitz arch bridge at Paris. The clear distance between docks was to be 1,312 feet, and that between towers centres 100 feet additional, making it longer than any arch yet built. The runaway deck had provision for a footwalk but was without stiffening trusses, and it supported a double line of track, so that cars might start from each side of the river at the same time. Towers were 33 by 112 feet, and 164 feet high and they had elevators to carry passengers to the upper crossing. A somewhat similar bridge, though not a transporter, was proposed by Max Ende for crossing the Thames at London. In the last case, instead of using suspended cars, travel of all kinds was to be raised and lowered on elevators running on inclined tracks at the ends, and descending into pits below the streets at each side of the river. (See Tyrrell's *History of Bridge Engineering*, page 336.)

The Marseilles transporter of 1904 is similar to that at Nantes, with cantilever arms and a centre span. Towers stand on cylinders and are 541 feet apart on centre, and the runway deck which was erected by cantilever method, is 160 feet above the water.

Up to this time, transporter bridges had not been used in America, though they are quite as suitable for harbor entrances here, as in Europe, but in 1905, the first and only one on this side of the Atlantic, was completed, over the ship canal from Lake Avenue, Duluth, to Minnesota Point. The site had been a perplexing one for bridge engineers, for they had wrestled with the problem for fifteen years or more. In 1890, Mr. A. P. Boller made plans for a swing bridge revolving horizontally on a shore pier, with a clear opening of 200 feet and deck 20 feet above water, the estimated cost being $400,000. As this was more than the city cared to spend, a prize of $1,000 was offered for the best design for a movable bridge to suit the place, and in response, twenty or more plans were prepared and submitted. Estimates were also submitted for a double tunnel, varying in amount from $500,000 to $1,300,000. In 1899, when the bridge at Rouen had been completed and publicly illustrated, the city engineer, Mr. T. F. McGilvray, prepared drawings for a similar bridge to cross the channel at Duluth with a clear opening of 300 feet, or 383 feet between tower centres. French engineers having discovered the lack of rigidity in suspended tracks for short span transporter bridges, were planning a new one for Nantes on the cantilever principle with an intermediate truss, similar in some respects to that proposed by Charles Smith in 1873 for Middlesborough. An alternate plan to that prepared by the Duluth city engineer, was also made in 1901 by a local agent of the American Bridge Company that was tendering for a construction contract. In this plan (Fig. 5) rigid framing was used throughout, the distance between front tower legs being 393 feet, 9 inches, and the height beneath the bridge 135 feet, as at New York City. As the structure from its exposed position would certainly

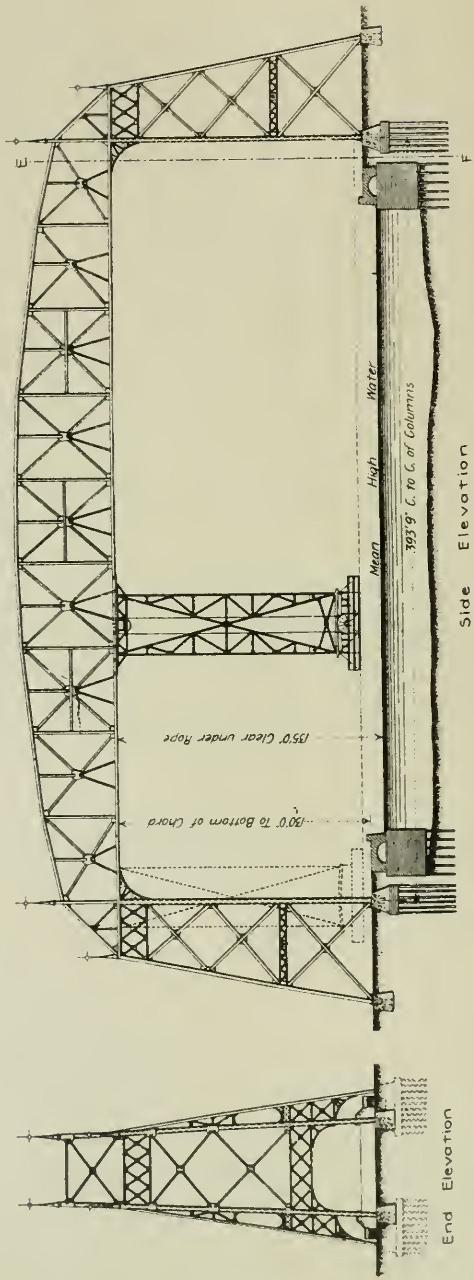
E
F
Mean High Water
393'9" C. to C. of Columns
135'0" Clear under Rope
130'0" To Bottom of Chord
Side Elevation
End Elevation

Fig. 5

be subject to severe gales, every effort was made to secure rigidity, double riveted web systems being used in the trusses and stiff braced members for the car suspenders, thus preventing it from swaying in the wind. Several types of construction had previously been used for transporter bridges in Europe, those at Bilbao, Bizerta, and Rouen, being suspensions; Nantes and Marseilles, cantilevers; and the proposed one at Bordeaux an arch; and it is interesting to note that still another type—a simple truss—was selected for the bridge at Duluth, to which, with its comparatively short span, it is well adapted, at the same time making a patent more easily obtainable. In several European designs, the moving car passes through the towers which are braced laterally to resist wind pressure, but in the Duluth bridge the platform runs in between the front columns only, without interfering with the tower bracing on the outer side. The car is suspended from a rigid trolley frame, the wheels of which, mounted on roller bearings, run on rails inside the box chords. The car is propelled by electric power from two different scoures, a one-inch steel rope being fastened to each tower and wound on a drum attached

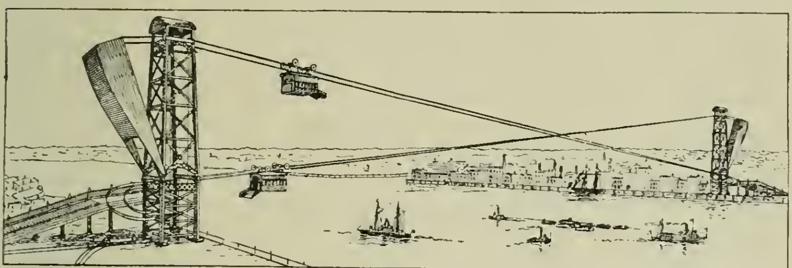

Fig. 6

to the moving part. When moved by electric power, the car crosses the canal in one minute, but it also has hand power for emergency. Both trolley and car run against air buffers at each end, and jar is further avoided by links in the suspenders near the deck. Construction was under way more or less for four years and after much delay, change of contractors, and revision of plans, it was finally completed in 1905 at a cost of $100,000, though a number of ornamental features that were at first intended were omitted.

Another very interesting design for a modified type of transporter bridge appeared in 1905, the invention of Abraham Abelson of New York, the essential principle of which was gravity car motion. As will be seen from the illustration (Fig. 6) at each side of the river or ravine, towers are erected, to the base of which double cables are attached, which, after crossing to the opposite side, pass over saddles at the tower tops and fasten to counterweights hinged to the opposite side. This method of fastening the cables avoids the obstruction caused by carrying them back in the usual way to anchor blocks on shore, and at the same time holds the cables taut though not absolutely rigid. The same anchorage principle is now applied in modern

freight cableways and is effective in allowing for expansion or slight variation in the cable length. The effect of the hinged weights counteracting the pull on the cables is to produce vertical reactions on the towers, without any tendency to tipping. An elevator operates in each tower, and a car on crossing from the other side makes a detour around the tower to the land side and is then loaded on the elevator by which it is lifted to the upper level. The car trucks are swiveled that they may be easily removed from contact with the cables and attached to them again in their raised position. The cars are not connected with each other and their speed may be regulated by the operator.

Although transporter bridges have been projected in Great Britain for forty years or more, none were built there prior to 1905, but since that time four fine structures have been completed at Runcorn, Newport, Warrington and Middlesborough, three of which were the designs of English engineers. A suspension over the Mersey at Runcorn was proposed in 1817 by Thomas Telford though never built. His design showed a clear span of 1,000 feet with stone towers, a roadway 30 feet wide, and a clearance of 70 feet above the water, the estimated cost being $450,000. But the river at that place remained unbridged until 1868, when the London and North Western Railway erected a bridge 1,300 feet long in three spans, with an under clearance of 78 feet, to the deck of which pedestrians had access by stairs at the ends. The new suspension transporter crosses the Mersey and the Manchester Ship Canal between Widnes and Runcorn with a span of 1,000 feet, and an under clearance of 82 feet, or slightly more than that at the railway bridge near by, and it is now the longest highway span in Great Britain. It consists of a stiffened track, hung from cables passing over metal towers on shore, high enough to permit ships to pass under, the cables being anchored back into blocks of masonry. The two main cables are 12 inches in diameter and are cradled according to the method first used by John A. Roebling in 1844. Each cable is composed of nineteen smaller ones, and the whole is wrapped and protected from the weather by canvas and bitumen. The angle of inclination which the cable makes with the vertical is different at each side of the tower, and the stress in the back stays is, therefore, about 12 per cent. greater than in the span. Where they bear on the saddles at the tower tops, the cables and saddles are clamped together to prevent slipping and to insure vertical reactions. The cables at the ends are attached to bars or links which are anchored into blocks of masonry, the bars being embedded solid in concrete after receiving the stress from dead load. The double towers on each shore are gracefully proportioned tapering out towards the base like the trunks of great trees, and they are connected by ornamental portals and diagonal bracing. Each one is composed of four columns forming a rectangle 30 feet square at the base, the transverse distance between tower centres being 70 feet. A stair at each end gives access for pedestrians to the elevated foot walk. Under each tower leg is a cast iron cylinder 9 feet in diameter with 1 1-8 inch metal, the interior of the cylinders

being filled solid with concrete. The stiffening girders are 18 feet deep and 35 feet apart, the two halves being connected at the centre by hinges. The moving platform or car is 24 feet wide and 55 feet long, with a single road and a covered space for pedestrians at one side. It weighs 120 tons and the usual time for crossing is 1¾ minutes, the moving being controlled by a man in an elevated cabin on the car above the roadway. The car is suspended from a trolley 77 feet long, mounted on wheels 18 inches diameter, and running on the track of the elevated deck. It is propelled by an electric motor on the trolley which is supplied with power from a generating station near by. The engineers were J. J. Webster and J. T. Wood, and the contractor, Sir William Arrol & Co., the total cost including approaches being $665,000. It was formally opened in May, 1905.

A bridge over the Usk at Newport in South Wales, designed by F. J. Arnodin and R. H. Haynes was under construction at the same time as the last one described, but though sanctioned by Parliament in 1900, work was not completed until 1906. A stone bridge in five spans was placed over the river in 1800, and it was repaired and widened in 1866 and 1882, and yet another bridge or better crossing facilities were needed. Preliminary designs and estimates for bridges of different sorts showed that a high level structure would cost $6,250,000, and a low level bridge with a swing span, about $3,500,000, the cost in both cases being much greater than the authorities cared to pay. The design for a transporter bridge which was accepted is of the suspension type, with a length of 645 feet between tower centres, and 592 feet in the clear, the distance between centre of anchorages being 1545 feet. The headroom above the water is 177 feet, and the design in general is somewhat similar to Arnodin's other suspensions. Towers are pin-ended and their tops are 242 feet above the approaches and 269 feet above low water. Each tower contains 277 tons of steel, and stands on four cylinder piers. Sixteen smaller cables were used instead of a single large one at each side, as on the bridge at Runcorn, conforming with the usual French custom. The traveler which is mounted on sixty cast steel wheels, is 104 feet long and 26 feet wide, and from it is suspended the moving car, 33 feet long and 40 feet wide, weighing 51 tons. It is capable of carrying a live load of 66 tons and its maximum rate of travel is 10 feet per second, being propelled by wire rope and electric power. The cost in detail was as follows:—

Foundations	$95,600
Shore abutments	18,400
Superstructure	140,000
	$254,000

The third bridge of the kind in England crosses the Mersey at Warrington, 18 miles from the larger one at Runcorn. It was erected chiefly for the convenience of employees at the manufactury of Joseph Crosfield & Son on a strip of land known as Tongueland, between adjoining bends in the river. It is of suspension type and has a span between towers of only 250 feet, with an under clearance

of 75 feet as required by government. Stiffening trusses are without hinges and were proportioned according to the theory of Merriman and Jacoby. Single cables 7 inches in diameter of plough steel wire were used at each side, the economical sag for the specified load being found by trial to be one-twelfth of the span. The horizontal track is suspended from the cables by 1¼-inch rods, 10 feet apart, and from this track the car, which has a capacity of only 5,000 pounds, is hung. The accepted design was submitted by Thomas Piggott & Co., of Birmingham, the resident engineer on the work being James Newall.

The transporter bridge over the Tees between Middlesborough and Port Clarence, forming a connection between North Yorkshire and Durham County, though proposed in 1873, and elaborate plans then prepared, was the last of four in England to be erected, for it was not formally opened until October, 1911, after twenty-seven months of actual construction. It consists of double cantilevers on metal towers anchored at the rear ends to blocks of masonry, and in many respects is similar to the design previously made for the same site by Charles Smith of Hartlepool. The span between centre of towers which are 225 feet high, is 570 feet, and the total length is 850 feet. An elevated foot walk over the bridge is reached by stairs in the towers. The moving car is 41 by 39 feet, with space of six carriages and 600 persons, and it is moved by an endless rope. It contains 2,600 tons of steel with 600 tons in the foundation, and the total cost was $408,000. It was designed by the Cleveland Bridge and Engineering Co., and built by Sir William Arrol & Co. Another bridge of suspension type with pin-ended towers 390 feet apart on centres, was erected at the Kiel Dockyard in 1911.

From the above brief descriptions, it appears that transporter or ferry bridges have a definite use, and are especially applicable for harbor entrances on the sea coast or at other exposed positions, where ships which are unfamiliar with local drawbridge signals, are frequently entering, or where they may be driven for safety during storms. To shipping, they offer nearly all the advantages of a high level fixed bridge, and still permit land travel to cross at about water level, at the same time saving the expense of inclined approaches to a high level structure.

Illustrations are from Tyrrell's *History of Bridge Engineering*, *Engineering News*, and *The Scientific American*.

D. L. H. Forbes, '02, has been appointed consulting engineer for the Trethewey Mine, at Cobalt. Mr. Forbes' office is located in the Manning Chambers, Toronto. S. M. Thorne, '00, is his assistant at the Trethewey mine.

F. A. Gaby, B.A.Sc., '03, has been appointed chief engineer of the Ontario Hydro-Electric Power Commission, succeeding Mr. P. W. Sothmann, who has occupied that position during the last six years.

STEEL RAIL FAILURES

By H. Hyatt, B.A.Sc.

PART II.

The June issue contained the first part of this article dealing briefly with the evolution of the steel rail as used to-day, and to some length with the design of its cross sections, the first of a classification into four groups into one of which, or a combination of two or more, the causes producing failure are likely to fall. This article continues a study of these causes by considering the remaining three divisions of the classification, and concludes with a summary of remedies that have been adopted and are now in use as a deterrent to the many accidents attributed to rail fractures.

Chemical Composition of the Steel

The chief constituents of rail steel which are liable, or said to be liable, when present in excessive or inadequate quantities, to cause the failure of rails when in service, are carbon, phosphorus, and sulphur. Besides these the other common constituents are silicon and manganese. Still further, there are a number of substances, such as nickel, vanadium, manganese, titanium, etc., which are employed to form alloy steels, and these alloy steels are coming into use in the manufacture of rails, though none of them are common as yet, nor have they been in use any great length of time, and data as to actual results are consequently very meagre.

As is well known a high carbon steel is a hard steel which will resist wear, but if carbon be present in rail steel in too great a quantity the rails are brittle and liable to fail when put in track. On the other hand, too small a percentage of carbon gives a steel which is too soft to resist either abrasion by the wheel treads or crushing by the wheel loads. Another difficulty with high carbon is that the higher the carbon the greater is the liability of its becoming segregated. As is also well known, an excess of phosphorus will likewise produce brittleness. With regard to sulphur a definite statement cannot be made. Sulphur is entirely omitted in some specifications since it is taken for granted that it will be reduced to a minimum by the manufacturer on his own account because a high sulphur steel, where the sulphur is in the form of iron sulphide, can be rolled only with difficulty if at all. There are, however, some who believe that that small percentage of sulphur which remains in the finished rail is, particularly in the form of manganese sulphide, a prime factor in a great number of failures.

Another portion of the discussion which belongs under this section is the often heard proposition that all rail steel be manufactured by the Open Hearth Process in place of the Bessemer. This is due to the fact that the Bessemer process cannot be used to reduce the percentage of phosphorus in an ore while the good Bessemer low phosphorus ores on this continent are becoming worked out. While

chiefly on a more or less experimental basis there have nevertheless been a considerable number of open hearth rails manufactured, but it is still too early to say whether the experiments have been altogether successful or not. The fact remains that rails are for much the greater part still being made by the Bessemer process, not only on account of its being less expensive, but also because there are not a sufficient number of open hearth mills to supply the demand for all the rails that are required, and hence in considering rail failures the Bessemer process must be taken into account.

The combination of carbon and phosphorus in rail steel is another important point, but the exact proportions of each that are advisable is evidently a matter of doubt. For instance, the Rail Committee of the American Railway Engineering and Maintenance of Way Association report in 1910 that, "We believe it necessary to submit a sliding scale for the percentages of carbon and phosphorus, which provides for increasing the carbon as the phosphorus decreases. The American Railway Association specification calls attention to the matter in the following words: 'When lower phosphorus can be secured, a proper proportionate increase in carbon should be made.' The amount of increase is not provided for in the specifications, and this appears to us to be necessary in order to secure uniformity of practice; otherwise the fixing of these percentages becomes a matter of special arrangement. Bessemer rails are being furnished regularly with phosphorus under the maximum allowed, and when this is done, the carbon should be raised above the higher limit now fixed in our specifications, or a soft and poor wearing rail will result; yet this condition has not been fully guarded against in rails furnished under existing specifications. The lower and upper limits for carbon have heretof re been fixed with the intention that the mills furnish rails with a composition as near between the two limits as possible. The mills, however, in order to meet the prescribed tests with the least difficulty, keep both carbon and manganese as nearly as possible to the lower limits, with the corresponding result that a generally poor-wearing rail is furnished."

With regard to the same question, Benjamin Talbot writes as follows: "The treacherous nature of steel, high in carbon, manganese, and phosphorus, is well known. Any increase in the carbon accentuates this danger. A point, however, which has not been so well dwelt upon is whether high carbon steel, even though low in phosphorus, is not in some cases dangerous, due to the fact that segregation will take place, sometimes to a very marked amount. The Pennsylvania Railroad has specified that open hearth rails must have 0.8 to 0.9 per cent. carbon for 90 to 100 pound rails with 0.03 per cent. phosphorus. Undoubtedly this steel should form a very excellent material for rail purposes if it could be guaranteed that no segregation of the carbon would take place whereby one part of the rail might become still higher in carbon and so cause the material to become brittle. It will be of interest to learn how such high carbon rails behave in practice, and especially how they stand shock under low temperatures. Possible rails with 0.75 per cent. carbon, 0.03

per cent. phosphorus and manganese not above 0.7 per cent. will give the best results."

Also on the same question we quote P. H. Dudley: "The actual wear of the 80 and 100 pound rails which I made at Scranton, with 0.60 to 0.65 per cent. carbon and phosphorus 0.006 per cent., after twelve to fifteen years service only show a loss of metal from the top of the head of from 3-32 to 1-8 of an inch. This is a slow rate of wear, and for 100 and 80 pound rails, is a much better result than can be obtained with metal having 0.10 per cent. phosphorus. The wear in that class of metal is from three to four times greater than it was with the high carbon and low phosphorus."

With regard to manganese sulphide as a source of failure, Professor Fay of the Massachusetts Institute of Technology, has written that, "Sulphide when present as manganese sulphide has been declared to be harmless, but that it is an extremely brittle and perhaps dangerous material will be demonstrated. It must be stated at once that all manganese sulphide is not injurious, in fact most of it is harmless. The conditions under which it becomes harmful will be shown." Professor Fay then proceeds with a discussion of a number of breaks and calls attention to an almost invariable presence of manganese sulphide at the origin of fracture. It is a brittle substance in which fracture may begin and whence it may continue into the steel itself. The manganese sulphide is found in rails in elongated threads. This is explained by the demonstrated fact that manganese sulphide has a freezing point of 1162°C., whereas rail steel solidifies at about 1450°C. If rolling begins at any temperature above 1162°C., the manganese sulphide will be liquid from the temperature at which rolling began until it falls to 1162°C, and below this temperature, being in a plastic condition, it is elongated in the direction of rolling. Where rolling pressure is exerted on three sides, as in rails, it would appear as elongated threads. The author concludes from this that it is not to be doubted that manganese sulphide when existing in certain forms is a harmful constituent of steels, and continues with regard to remedies as follows: "Steels which are high in sulphur should not be rolled at too high a temperature, for if manganese sulphide is entrapped it will surely be rolled out into a form which will ultimately lead to trouble, but specifications should be so drawn as to limit the amount of sulphur in the steel. At the present time most of the specifications do not even mention sulphur. The next step is to allow the metal to stand a longer time after the addition of the ferro-manganese. With the specific gravity of manganese sulphide at 3.966 and that of steel at 6.82, it should rise to the surface and be skimmed off with the slag if given sufficient time. Usually this time interval, between the charging of the ferro-manganese and the pouring of the ingot, is very short. The desire of the manufacturer to increase his output has led him to cut down the interval to the shortest possible limit with the natural consequence of a large number of broken rails. A longer time interval will allow the metal to purify itself. If, on the other hand, it is not permissible to start with a low sulphur ore, or a sufficient time interval for the

removal of the manganese-sulphide, resort must be had to electric refining of the molten metal by means of a basic slag."[1]

Concerning alloy steels, or steels containing a high percentage of various materials introduced to give the steel some special mechanical qualities, something should also be said, since it is probable that the more general use of such steels in the manufacture of rails would have a decided influence on rail failures. Some of the alloys best known at the present time are manganese, nickel and chromium. Manganese in particular is being employed in the manufacture of frogs. Those alloys fast coming into use among employers of steel, but which are rarer than the three first mentioned, are tungsten, molybdenum, vanadium, uranium and titanium. The actual effect of these alloys is not well understood even by expert metallurgists, but there is not much doubt but that they add valuable qualities to the steel.

The alloy which is particularly considered as a valuable one in connection with rails, it titanium. For instance, A. W. Thompson, Chief Engineer of the Baltimore and Ohio, says that titanium has been used by his road, and that its use has resulted in a rail with a composition high in carbon and phosphorus, but which even then successfully passed the physical test. Tests in the track are, however, too immature as yet for consideration. G. B. Waterhouse also makes reference to the same subject, and says that titanium when rightly applied in the proper amount is found to retard segregation of sulphur, phosphorus, and carbon in what is normally quiet quick-setting steel. And, referring to the contention of some for an increase in the discard, is of the opinion that in all commercial steels the bulk of the ingot must be used, and hence he believes the experimental results obtained with the use of titanium to be of importance, showing as they do, one way in which segregation may be considerably controlled.

Manufacture of the Steel and Rolling of the Rail.

When it is considered that the loads which the rail has to carry are not excessive, and that the supports upon which the rail rests are ample, it logically follows that if the rail fails it must be composed of defective steel, also that defective steel is the result of faults in the manufacturing process. This is the position taken by the greater number of railroad engineers and officials with regard to the failure of rails during their service in track. On the other hand, those engaged in the manufacture of the rails take the position that the premises stated above will not hold, that the loads which the rail has to carry are excessive, and that the supports carrying the rail are not sufficient. There are points that can be offered in favor of both sides of the question. In this section it is proposed to state in a very general way the chief criticisms that have been made with regard to the many details of steel manufacturing as either sole or contributory factors of the abnormal number of rail failures which have occurred and which are occurring.

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1 Henry Fay, Proc. A.S.T.M., Vol. 8, pp. 74

Since the time when the manufacture of steel rails was first established on a commercial basis, there has been a continual endeavor on the part of the manufacturers to turn out the product in the shortest possible space of time. This endeavor has been eminently successful, provided that the quality of the steel rails has at the same time been maintained. But this, according to many authorities, is where much, if not the greater part of the trouble with rails has originated. They claim that the time of manufacturing has been cut down to such a small period, that, with the methods in vogue, it is impossible for good, sound, homogeneous steel to be the product. They claim that an insufficient time is allowed for the chemical reactions to be properly completed; that the working and rolling of the steel is done too rapidly; and that, in endeavoring to still further cut down the time, the reductions per pass are made too heavy; that the passes are too few in number, and that the process of rolling is carried on with the steel at too high a temperature; not to mention other items which go toward completing a formidable list. All such practices tend toward the final production of rails composed of poor steel, and poor steel in turn tends towards failure.

The manufacture of steel is a chemical process and every chemical process requires time if the reactions are to be complete. Hence, if a good steel ingot is required time must be taken between the pouring of the steel into the ladle and the teeming of the steel into the ingot mould, in order to allow thorough chemical reactions, the entire escape of the gases, and the separation of the slag. Unless such time is allowed before teeming is commenced, the reactions but partially complete themselves in the setting steel of the ingot, and the slag oxides and the gases are often entrained instead of eliminated. The minute globules or particles of slag from the reactions caught in the columnar structure, also in the secondary zone of blow holes, with or without associated oxides, are important factors in the checking of the tender skin of the ingots in blooming, and the subsequent tearing of the flanges as their extreme edges must slip in the passes of the rolls. The slag and occluded gases in connection with segregated metal are important factors in the split heads of rails, which develop between the ends after a short or a long period of service, depending upon the thickness of the metal in the bearing surface over the entrained slag and occluded gases.

Too rapid rolling of the steel rail has bad results in two directions. In the first place, if the reductions per pass be too great the steel is torn, instead of being simply squeezed or compressed, with the result that large cracks are developed in the steel, and there is no subsequent operation of the rolling process that will weld these cracks up. The cracks are elongated and may apparently disappear, but the defects are still there, and I believe that many a subsequent mysterious failure of rails made from such ingots, if we could trace it back, would be accounted for by the cracks developed in the blooming rolls. Secondly, the short time during which the rail undergoes rolling results in a steel which is not sufficiently worked, and hence a steel is produced of a coarse granular structure. The rails made to

the larger sections necessarily receive less work than did those made to the smaller, and in addition to this, the diameter of the rolls has been increased, the power of the engines driving them has been increased, and the number of passes used in rolling the rails has been decreased. Each of these items tends towards a decrease in the working which the steel receives, and therefore, towards steel of a poorer quality.

The rolling of the steel when it is at a high temperature makes the rolling more easy, and the time of shorter duration, but the consequence is that rolling comes to an end with the steel still at a temperature far above the critical, and hence this is another practice which tends towards the production of low quality steel. The later specifications guard against this by stipulating that the finishing temperature shall be such that the shrinkage after leaving the hot saws shall not exceed a certain specified number of inches. In order to comply with this specification it is said that some mills have held the rails before the last pass while the temperature fell, and this, of course, is a practice which is just as detrimental to the finished rail as the first.

The reduction of the time taken for the manufacturing process has thus led to a number of bad effects in the finished rail; general unsoundness due to the incompletion of chemical reactions; the entraining in the steel of slag particles, manganese sulphite, blow holes, etc., causing defects in the final product; and coarseness of structure and additional unsoundness due both to decreases in the amount of work done on the steel and also to the high temperature at which rolling occurs.

Another detail of the manufacturing process, about which much discussion has taken place with regard to its bearing on rail failures, is the quantity that should be discarded from each ingot in order to eliminate what is generally recognized as the poorer portion—that portion in which segregation and piping are most likely to occur. The discard of a large percentage of the ingot is an expensive item and the percentage is therefore kept down as low as is possible, but some roads have found it advisable to specify a crop of as much as 30 per cent. For instance, the Baltimore and Ohio some six years ago decided to increase the crop from 5 to 30 per cent. and by so doing increased the removal of rails from the track, on account of split heads during the first year of their service, from 22 to 1.75 per cent. On the other hand we read that of all the rails put in track by the Pennsylvania Railroad only about 1-40 of one per cent. failed in any one year. Assuming the average life at eight years this would be 1-5 of one per cent., so that in discarding 25 per cent. we would be discarding 24 and 4-5 per cent. of metal for the sake of eliminating 1-5 of one per cent. It may be stated further that a specification making such a waste unnecessary is one which calls for the testing to destruction of the crop end of every ingot, and, if piping is shown, all the top rails from the heat are to be rejected. This gives about a 30-per cent. discard from all heats which show piping, while those which do not show piping are cropped but a small amount.

The specifying of a certain large percentage crop from all ingots,

while it seems to secure the necessary results, is nevertheless a wasteful expedient to employ for every heat of rail steel, and that specification is the best which leaves the discard to the manufacturer and safeguards the product by proper tests. If the test piece is chosen from such a location, and if the rejections made according to the test are sufficiently severe that it will be to the interest of the manufacturer to discard all poor metal on his own account, the object in view will be attained, and in addition to this it will stimulate the use of better manufacturing methods which will reduce piping and segregation to a minimum.

Still another detail which is discussed with regard to its bearing on the production of sound rail steel is the size of the ingot. There are those who consider that the size of the ingot should be reduced since a large ingot necessarily leads to increased segregation, which is, it gives areas of metal which contain large percentages of phosphorus or carbon, a decided factor of the general conditions leading to failure. On the other hand, there are others who advocate an increase in the size of the ingot in order to obtain the same amount of working for the steel during its reduction in the rolls as was given to the smaller rails. If the ingot remains of the same size while the rails increase in weight it follows that the work put into the steel is not so great, and hence larger ingots are necessary. But the larger the ingot the greater is the proportion of segregation and piping. There are thus arguments to be advanced in favor of both increase and decrease, and a mean must be sought unless segregation and piping can be reduced by other means.

These are the most important parts of the manufacturing process that have been discussed as factors in the rail failure problem. In addition there are a large number of other details, such as the production of low carbon areas due to the introduction of foreign substances in the ingot moulds to prevent trouble with the stools, and failures originating in fractures made during the process of gagging.

As in considering the chemical composition of the steel, so in considering the manufacturing process in general, the open hearth process is often mentioned as the remedy for a great proportion of the trouble that is found in connection with the Bessemer process. But for the most part the same precautions must be observed in manufacturing steel by the one process as by the other, and there is considerable doubt as to whether the open hearth rail would prove to be of any better quality than the Bessemer. If time and money be employed in the future, as they have been employed in the past over the commercial development of the Bessemer process, in getting sound ingots, free from blow holes, slag, manganese sulphide, segregation and piping, the Bessemer process should prove to be more economical, in the true sense of the word, than the open hearth for the production of steel for rail purposes.

Roadbed Conditions and Effect of the Rolling Stock

Given a rail of the proper section and composed of good steel, failure may still occur by reason of the rail being placed in a bad

piece of track or on account of defects in the rolling stock. In any track the rail acts as a girder and is designed in order that it may do the greatest part of the work of distributing the wheel loads to the roadbed. The design is governed by the static wheel loads increased by an impact allowance, by the character of the support the rail is expected to receive, and by a certain factor of safety which is expected to cover any extra stress occasioned by the severe service to which the rail is put. If the support which the rail receives is such or if the rolling stock produces stresses such that the extra material provided to resist everything beyond the static loading is not sufficient, then the elastic limit of the steel will be exceeded and the rail will fail. It is essential, then, that the roadbed be kept in such condition that the support received by the rail is at least as rigid as was expected by the designer, and that certain defects in the rolling stock, which produce greater stresses in the rail than are necessary, be eliminated.

The consideration of the proper support of the rails involves a great part of the whole question of maintenance of way—a question which cannot be properly discussed here. The principal points can, however, be pointed out.

Not considering the factor of safety, rails are designed with the understanding that they shall present a smooth surface to the passage of traffic, and if the track is not properly graded, the impact effect of the load-carrying wheels on the rails will be greater than that for which allowance was made. The ties must be properly tamped, and must present a wide smooth face to the base of the rail, in order that the immediate support of the rail may be sufficient. Owing to the diminishing supply of timber the face of the tie is becoming narrower--a condition which increases the strain in the rail--and it is a possibility that even at the present time this extra strain is one of the elements of the rail failure problem. The joint material contributes towards the support of the rail, but rail failures are but very rarely attributed to imperfect joints. The ballast must be maintained of a proper thickness in order that it may hold the ties in place, distribute the loads evenly to the subgrade, and keep water from the immediate vicinity of the ties.

That portion of the roadbed, which, by its failure to give a sufficiently rigid support to the rail, causes more rail failures than any other portion, is the subgrade. The same rail, with traffic of the same intensity and volume, will have far less failures if the subgrade is sandy, porous, and free from water than if the subgrade is dense, water-soaked clay. The problem in this connection consists in eliminating water from the roadbed—an elimination that cannot be too thoroughly made if rail failures are to be avoided.

Among those defects in the rolling stock which cause rail failures may be mentioned the imperfect counter-balancing of locomotives, and flat spots on wheels—particularly on the driving wheels of locomotives but also on the wheels of cars. Both imperfect counterbalancing and flat spots on wheels are known to have caused quite a number of rail failures, but, at the same time, both causes are in greater part removable by proper precautions being taken in

the car repairing shops and the failures arising from such causes are comparatively few in number.

Other causes of rail failure, which have their origin after the rail is put in track, and to which reference may be made in this connection, are, first, brittleness of the rolling surface due to its toughness having been exhausted by the cold flow caused by wheel pressures, second, burning and crystallization of the rail metal due to the slipping of locomotive drivers, and third, the stresses due to those changes of temperature, which occur while the rail is in track.

With the exception of soft and water-bearing subgrades the causes mentioned in this section are of a secondary nature.

Conclusion

Definite conclusions with regard to the problem presented by the frequent fractures of steel rails in service cannot be drawn from a reading of the available literature on the subject. A complete determination of the problem, from which conclusions may be drawn, can be made only by one having a large and varied practical experience in track work, in steel mill methods, and in the processes of examining and testing steel, together with the collection and arrangement of innumerable data. There are, however, several outstanding features of the problem which may be noted to advantage.

First, there is an evident necessity for some change to be made in the rail cross-section in order to do away with the difficulty at present experienced in the process of rolling the heavy sections, due to the large mass of metal in the head carrying the heat so much longer than the thin metal in the web and flanges. A remedy is to increase the weight of the rail by making both flange and web of a greater thickness. Second, the advantage to be gained by counteracting the effects produced by the high phosphorus usually present in the Bessemer rail. Third, the necessity of exercising more care in the manufacture of the steel and in the rolling of the rail. Such a precaution will require the expense of a greater length of time than is now spent in the making of a rail, but there seems to be but little if any doubt that such expenditure, if it be made judiciously in giving more time for the complete reaction of the various chemical processes involved, and in subjecting the rail to a more gradual and complete working during the process of rolling, will prove to be of the greatest advantage when a perfectly satisfactory rail is the desired product. Fourth, the advisability of providing a good, sound, porous, and well-drained subgrade throughout every mile of main line track.

It will be noticed that, as is usually the case, the improvement of the rail in any way calls for additional expense, and there are two ways in which this additional expense may be met—either by a reduction of the profits of the steel manufacturer or by the payment of an increased price by the railroads. Which method of the two is the just one we do not know, but, with the exception of accidents, it would appear as if the entire responsibility for the use of defective rails in track rested with the railroads. If, as some claim, they are

unable to obtain satisfactory rails from their manufacturer, they must obtain their rails elsewhere, but in any case they must obtain satisfactory rails even though an increased price must be paid. It is not as if a rail is worth so many dollars, and, if it be broken, so many dollars have been wasted. The railroads are responsible for the safe transportation of passengers and property, and the acceptance of such responsibility necessitates the use of sound rails.

ELECTRIC TRACTION AND ITS PROGRESS

By R. V. Macauley, B.A.Sc.

The steam railway operator no longer regards electric traction as unworthy of his notice, nor considers as mere effusions the claims advanced in support of electric operation as a practical solution of many of the grave problems that confront him in the course of modern heavy transportation. In fact, of late, railroad men have begun to take a very live interest in electrification, as is evident from the importance accorded to electric traction discussion by the various railway congresses and railroad engineering clubs. This change of heart has resulted from the more rational appreciation of heavy railroad problems by the electrical engineer, and, also, from the actual demonstration of the efficacy of electric traction under different trunk line conditions.

The subject of railroad electrification is a very broad one, embracing a great variety of engineering and other problems. The magnitude of the question is almost startling—it having been estimated that to take care of the heavy railway business of the United States for the year 1907 by means of electric locomotives, would require 24,000 locomotives worth $25,000 each, or an aggregate cost for electric locomotives alone of $600,000,000. It is thus evident that in such an article as this the limitations of time and space allow but a very limited treatment of certain phases of the general problem.

Trunk line railroad electrification necessarily refers largely to the conversion of existing steam-operated railroads into electric-operated roads; but it is important to note that in many cases new electric lines are operating under substantially the same conditions of traffic as obtain on many steam lines. At present many interurban and cross-country trolley lines are invading the field of the steam railway, and some of these lines have developed into quite extensive systems, operating over private right-of-way, and approximating in distances and speeds the conditions of steam railroads, but differing from steam railways in the elaboration of provisions for train-handling, in equipment of line with stations, yards, signals, etc., and in the organ-

ization for conducting a general transportation business, local and foreign, in both passengers and commodities.

"Trunk lines" are understood to be "lines between large cities, having important terminals and a mixture of light and heavy passenger and freight traffic."

The discussion here will be found to refer wholly to American practice, there being but one or two remarks on European practice. The aspects of trunk line electrification, which are discussed, consist of the following: The history and status of electric traction on trunk lines, the three prominent electric systems and their characteristics, features of steam and electric operation respectively, the economics of electrification.

History and Status of Electric Traction

The first period in the application of electrical energy for transportation, from about 1830 to 1860 was marked by experiments in connection with permanent magnets, reciprocating motion, and later with chemical batteries of very limited capacity. The next period began with the development of the electric dynamo and its subsequent use as a motor. Between the years 1863 and 1887 a great number and variety of miniature electric railways, and later heavier street railways, were built, and operated for short periods. The next period, and a very brilliant one for electric railways, may be said to date from 1888, for in that year the first commercially successful electric street railway in America began operation. It was installed by the Sprague Electric Railway and Motor Company, at Richmond, Va., and is the pioneer of the now familiar trolley systems seen in the streets of our cities and on the highways of our country. The next period of activity began about 1893, when the practical application of electricity for traction under conditions comparable with those obtaining on steam roads, took place.

In 1893 the Intramural Railway, at the Chicago World's Fair, first demonstrated the availability of electricity for heavier traction purposes than street railways. The distinctive feature of this installation was the first use of the third rail.

In 1895 the Metropolitan Elevated Railroad, of Chicago, was built, thus utilizing the principle which had been demonstrated by the Intramural, and three years later a considerable advancement was made when the "Multiple-Unit System" was first put into service by the South Side Elevated Railway of Chicago. This installation displaced steam locomotives, which course was afterwards followed by the elevated railroads of New York City.

The first real invasion of the steam railroad field occurred in 1895, when the Baltimore and Ohio Railroad began to operate all of its ordinary freight and passenger trains through the Baltimore tunnel with heavy electric locomotives. These electric locomotives were designed for pusher service through the tunnel, which, although not long, contained a heavy con-

tinuous grade. This installation clearly demonstrated the physical possibility of heavy electric traction.

The next large heavy traction electrification was that on the Long Island Railroad (one of the Pennsylvania roads), which was put into operation in 1905. The traffic consists almost wholly of a dense local suburban passenger service out of New York City. This electrification, which is one of the most important in America, is thus described by Mr. J. A. McRea: "In 1905 the Long Island Railroad began electric operation in connection with what was known as the Atlantic Improvement, which consisted of the elimination of numerous grade crossings in the borough of Brooklyn, and the re-construction of about nine miles of road. These improvements made necessary the elimination of steam as a motive power, and the work on these nine miles spread out until about 30 route miles were equipped to start with. This has been constantly extended until we now have about 62 route miles of road and 164 miles of track electrified. To a great extent the change was gradual, and, consequently, at no time was it necessary to change our methods, so to speak, over night."*

The Long Island electrification was followed in 1906 by a similar equipment of the West Jersey and Seashore (another Pennsylvania line) Railroad, a line running from Camden to Atlantic City (a distance of 65 miles). For 30 miles out of Camden the road serves a suburban territory, but on the remaining portion the local traffic is small. This may be considered the first example of electric traction for main line express service.

In 1906 the New York Central and Hudson River Railroad began electric operation of its New York City terminal. This is the first example of a very heavy trunk line terminal electric operation for all passenger trains. In connection with the electrification, the terminal was remodelled to secure greater capacity and convenience. It is planned to extend the electrified portion on both the Hudson and Harlem divisions to embrace a large suburban zone.

The New York Central electrification was followed in 1907 by the equipment of the New York, New Haven and Hartford Railroad into New York City, dictated primarily by the condition of its entrance over the New York Central tracks into the Grand Central Station. The first equipment was designed to conduct, by electric locomotives, a very dense local and through service on a four-track railway for 34 miles out of New York City. Of this distance 13 miles are over New York Central tracks. This initial electrification covered about 100 miles of single track, but greater extensions have since been made.

In 1910 the management of the New York, New Haven and Hartford Railroad decided to extend their electric service to

* "Notes on the Electrification of the Long Island Railroad," by J. A. McCrae. Proceedings of New York Railroad Club. March, 1911. Page 2354.

cover passenger, freight and switching service under trunk line conditions on the Harlem River branch. This extension, which connects with the present main line electrification at New Rochelle Junction, will, when completed, enable all train and switching movements on the New Haven system west of Stamford to be made electrically. By this electrification some 200 miles of track, measured on a single track basis, will be added to the 100 miles already electrified.

In September, 1910, it was decided to electrify the Hoosac Tunnel and approaches, including yards at each end. On May 18, 1911, the first train was drawn through by electric power, while continuous electric operation of the total traffic was begun on May 27, 1911. (It might be stated that the Boston and Maine is a part of the New Haven system.) This electrification includes the tunnel, east and west portals, and yards at both ends, aggregating 21.3 miles of single track.

There was, therefore, 121 miles of track under electric operation on the New Haven system in the summer of 1911. The electrification of 200 miles (as before stated) more is now proceeding, while, doubtless, the New Haven extension, including 150 miles more, will follow.

The New Haven electrification may be regarded as the most important, distinctively trunk line, electrification at the present time on any railroad.

In 1908 the Grand Trunk Railway electrified its St. Clair Tunnel. This is an example of electric haulage of all trains through a heavy grade sub-aqueous tunnel. The tunnel is a link in the main line of the railway between Sarnia, Ontario, and Port Huron, Michigan. The electrification covers 12 miles of track.

In 1909 the Great Northern Railway completed the electrification of its Cascade Mountain tunnel, in the State of Washington. In this tunnel (as was also the case in the Baltimore, the St. Clair, and the Hoosac tunnels) the conditions obtaining with steam operation were very bad (it is on record that the temperature in an engine cab rose as high as 200 deg. F.), and a safer and more efficient operation was demanded. As the Cascade tunnel was recognized as the limiting feature of the capacity of the Great Northern Railway for hauling freight across the mountains, the desirability of electrification is obvious. The availability of water power was also a determining factor.

The first railroad to be built for the handling of both freight and passenger business, under substantially steam railway conditions entirely by electricity, was the Spokane and Inland Empire Railway. This road was first operated in 1906 (i.e., the single phase section). Notable features of the installation are: The great extent—160 miles of track under single phase; 58 miles of direct current interurban, known as Coeur d'Alene and Spokane Railroad; 52 miles of city street railway, known as

Spokane Traction Company; the utilization of water powers; the heavy grades and curves, one grade being 2 per cent. and seven miles long, with numerous curves.

In the autumn of 1910 the Michigan Central Railroad put its new Detroit River double track (double tube) tunnel into operation. Electric locomotives now haul freight and passenger trains through the tunnel. Previous to the construction of the tunnel, trains were taken from Windsor to Detroit and vice versa by car ferries, and operation in winter was very troublesome. The electrification includes tunnel and yards at each end; total mileage is 19.

On Nov. 27, 1910, the Pennsylvania Railroad began service on their New York City terminal system. The construction of the tunnels, terminal station, and the electric motive power in connection with this terminal has been described as the greatest railroad work in history. The service is a very heavy passenger load, through the local, into the heart of New York City. It is a most significant fact that the general scheme carried out was only made possible through the wonderful development of the art of electric traction during the last few years. This electrification covers 108 miles of track. As in other terminal systems of similar character in large cities, two methods of operation are in use, namely, heavy locomotive-hauled trains for through service (Pennsylvania Road), and multiple-unit motor car trains for the local and suburban service (Long Island Road).

The foregoing much-abridged review of heavy electric traction installations includes only the more important electrifications under steam railway conditions, and it is evident that electric traction is in extensive use under a great variety of conditions.

The history of railroad electrification shows that electric traction was first considered for special situations, where possibly, economy of operation was not the most important factor. Later, the field broadened, due to the demonstration of physical and financial advantages. The general trend of electrification on trunk lines has been, firstly, tunnel electrification; secondly, passenger terminal electrification, including suburban service; thirdly, small freight terminals and extension farther and farther from the centres of dense traffic.

Electric Traction Systems

For traction work in general, a great variety of electric systems has been proposed; for electric traction under trunk line conditions there are now three distinct systems in use, namely, the direct current, familiarly known as the "third rail" system; the single phase alternating current system; the three phase alternating current system.

It is of prime importance to know the costs connected with the various systems, and since costs are determined by the in-

herent characteristics of the systems, a knowledge of those characteristics is of interest and importance in comparing the systems. In this connection, brief analyses of the three systems before mentioned are given.

The Direct Current System

Direct current at 500 to 650 volts is in almost universal use for city trolley systems; 1,200 and 1,500 volts have been used of late years in several interurban lines, and it has been proposed (by Sprague, in America) to use 1,200 volts for trunk lines; but for heavy railroad service 650 volts is now standard, and bids fair to continue so in its particular field.

Power for direct current railway work is generated as three phase alternating current at convenient voltage and frequency, 25 cycles being almost universal. The voltage is raised by transformers, in groups of three, to the transmission voltage, which is chosen to suit conditions—33,000 volts being a common value for tower and pole lines.

A three phase high potential (11,000 volts to, say, 60,000 volts) transmission line is required, in order to secure economical transmission of power.

On account of the low voltage employed for distribution, it is necessary, in order to prevent excessive loss of power and excessive drop, to have sub-stations placed at frequent intervals along the line. The distance between sub-stations depends upon the character and amount of the railway service—for heavy locomotive trains, sub-stations will have to be placed very closely along the line.

These sub-stations contain lowering transformers in groups of three, and rotary converters (seldom motor-generator sets) for changing from alternating current to direct current, also the accompanying apparatus. Direct current sub-stations require constant attendance; this makes the operating cost high. Since the sub-stations are installed comparatively close together, and since railway loads fluctuate violently, the load factor of the converters is rather low; this fact means low efficiency of underloaded rotaries, also, a more serious fact, it means excess equipment having heavy fixed charges.

In connection with the converter sub-stations, storage battery installations are sometimes used to improve the load factor and to insure against stopping of trains when central station power is cut off.

To conduct the current to the trains, a heavy "third rail" conductor is used. This third rail is supported by insulators from the ends of the ties and may have various forms of "protection" to lessen danger to employees and passengers. To collect the current, a heavy contact shoe suspended from the locomotive or car is made to slide over or under the third rail. "Track return" is used, and to accommodate the heavy cur-

rents, the track rails must be heavily, hence expensively, bonded. For heavy railroad service it is often necessary, on single track lines, to supplement both third rail and track rails by heavy "positive" and "negative" feeders.

Direct current railway motors are of the "series wound" type. They have long been thoroughly tried and standardized, and are recognized as having characteristics most desirable for traction service. The recent introduction of interpoles has farther favored the design of these motors, and they are now built in extremely large sizes (1,000 H.P., also allowing 2,000 H.P. for half-hour period), and are capable of standing severest service.

For direct current motors rheostatic control is used in combination with the "series-parallel" system of motor grouping. With this system considerable power is wasted during acceleration, and there are but two or three (with four motors) efficient running speeds, namely, the "series" and the "parallel" speeds. However, since the advent of the interpole it has become practicable to employ field control for giving a greater speed range with efficiency.

The direct current system is convenient for the equipment of motor cars for multiple unit service.

The Single Phase Alternating Current System

Since the advantages of the single phase system are almost all due to the high potentials practicable with this system, it is customary to use much higher voltages with this type than with the direct current system. For heavy service, 6,600 volts and 11,000 volts are general, the latter being favorite where locomotives are much used. Two frequencies are standard, namely, 25 cycles and 15 cycles. 25 cycles is almost universal in America, while 15 cycles is now favored in Europe. The selection of a standard frequency is a very complicated problem. For trunk line service, in which locomotives are used, there seems to be little doubt but that 15 cycles is preferable to 25 cycles, and 15 cycle apparatus may gain a foothold in America in the near future. Stillwell says: "Concensus of opinion now is in favor of 15 cycles rather than 25 cycles for single phase working."*

For single phase railway work, either single phase or three phase generators may be used. The use of three phase generators make switching arrangements more complicated, but it also allows the utilization of polyphase current for shop use and similar service. It is not much more expensive to use three phase genrators for single phase distribution, as the new type of dampened field cuts down the rising voltage on the idle phase, making it possible to use three phase for commercial require-

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* Discussion on "The 1,200-Volt Direct Current Railway System." L. B. Stillwell Transactions A.I.E.E. Vol. XXIX Part 1. Page 20.

ments. The generators may be direct connected to the contact system—which is good practice up to 11,000 volt generators —or step up transformers may be used if desirable.

If the electrification covers a very considerable distance, say 25 to 50 miles each way from power house, with 11,000 volts, it may be desirable to use a high potential transmission line to feed the trolley system. This line would be single phase.

Single phase railway sub-stations are merely step down transformers, with their minimum of auxiliary apparatus interposed between transmission line and distribution system. Being very widely spaced, these sub-stations have the best possible load factor. The efficiency is high and no attendance is necessary. Thus it is evident that these sub-stations are cheap in first cost, and have low operating costs; also of great importance is the fact that they are few in number.

To show how widely sub-stations may be spaced, the example of the New York, New Haven and Hartford Railroad may be cited. On this road, 11,000 volt generators feed directly to the trolley system. No sub-stations are used, and at peak load (5.30 p.m.) the voltage at Harlem River Station, which is 25.6 miles from the central station, is 9,151 volts. This is claimed sufficient to maintain all passenger and freight trains on schedule, and to furnish at the same time the necessary power to switching engines doing duty on 100 miles of classification and switching yard tracks, which are a part of the Harlem River branch electrification, and which are located most remotely from the power house.

The working conductor in the contact system is an overhead copper, alloy, or steel wire suspended by means of "single" or "double" catenary arrangement in a plane, parallel to the track, and at a height above the track of about 22 feet in American practice. The catenary suspension system readily lends itself to all conditions met with in trunk line service, and notably for large freight yards. Track return is used, hence rail bonding is necessary, but bonds are light and inexpensive on account of the small currents carried.

The locomotives and motor cars collect current from the trolley wire by means of an overhead pantograph, which carries a contact shoe, bow, or roller. The line voltage is stepped down to the motor voltage by means of a transformer, which is arranged with a number of taps, for supplying various voltages to the motors. The type of single phase motor used is the series compensated type, which possesses characteristics very similar to those of the direct current series motor The single phase motor, however, is heavier than the direct current motor of similar capacity. It also requires a transformer of considerable weight, and, including the control apparatus, the alternating current equipment is much heavier than the direct current equipment.

Control of motors is secured by voltage variation, which

is easily obtained by the use of numerous transformer taps. The taps are taken to the controller after passing through a system of "preventive coils," the function of which is to obviate breaking the circuit and short-circuiting transformer coils, on passing from step to step. This method of control allows of very wide range of efficient speeds. Every controller position is an efficient running position; it also enables the motorman to compensate for drop in the line and to overspeed in case of delay.

As before mentioned, single phase equipment is heavier than direct current equipment, but it is obvious that the difference in weight will be only a small percentage of the weight of a heavy train. The conclusion is that the weight of equipment is a relatively unimportant item in the operation of locomotive trains with long runs, but for a high-speed, frequent-stop schedule, as carried out on many roads by means of multiple unit motor car trains, this item assumes greater importance.

Perhaps the most remarkable features of the single phase (series compensated) system are its simplicity and flexibility. As illustrating these two points, reference is again made to the New York, New Haven and Hartford Railroad electrification. The simplicity is well shown by the following statement by Murray: "The New Haven system provides that the volt manufactured in and leaving the doors of the power house is the same physical volt that knocks at the doors of the locomotives. Thus the line is the single link that unites the power house and the locomotives. All such adjuncts as step-down transformers, synchronous converters, storage batteries, low-voltage distributing systems, with their necessary complement of help, are dispensed with."* The flexibility is shown by the fact that the New Haven trains pass at full speed from the New Haven zone, in which 11,000 volts alternating current and overhead conductor are employed, to the New York Central zone, in which 650 volts direct current and a third rail conductor are employed. The motorman changes from alternating current control to direct current control or vice versa by simply throwing a set of double-throw switches. Of course, such interchangeability is accompanied by increase of complication, weight, and cost of equipment.

The Three Phase Alternating Current System

The three phase system is used in trunk line service by only one American road, namely, The Great Northern Railway, which has been referred to before. This electrification makes use of 6,600 volts at 25 cycles. The European standards are 3,000 volts and 15 cycles.

The power for this system is generated as three phase alternating current at desired voltage (3,000 or 6,000 say) and fre-

* "The Log of the New Haven Electrification," by W. S. Murray. Proceedings of A.I.E.E. Dec. 1908. Page 1658.

quency. If the system is at all extensive, a three phase high voltage transmission line is necessary.

Sub-stations for this system resemble the single phase railway substations, except that transformers in groups of three are used; also, due to the lower working voltage of the three phase system sub-stations must necessarily be more closely spaced on three phase than on single phase lines.

Two overhead conductors, suspended by catenary system are employed for contact. Due to the high voltage between the two lines, the overhead construction is difficult and expensive at switches and is prohibitive in large freight yards such as exist in America. Track rails are bonded as in the case of the single phase system.

On the Great Northern locomotives, transformers are used to step down the voltage to 500 volts, for the motors; in Europe 3,000 volts are used directly on the stators. With this latter system, drop on the line must be kept down to a minimum, as it has a serious effect on the motor torque, which torque varies as the square of the voltage.

The three phase induction motor is used on three phase traction systems. This motor is inherently a constant speed motor. This means that under ordinary circumstances it would run at almost the same speed up a heavy grade as on the level, although in the former case the horse power output would greatly exceed that required in the latter case. Changes of speed can be effected by changing the secondary resistance, but this is a very wasteful method. Cascade control is used to obtain lower speeds with higher efficiency than is obtainable with straight rheostatic control. Also, the synchronous speed may be halved by employing a system of "pole-change," that is, by changing over to one-half the number of poles. Both concatenation and pole-change introduce complications in the control system, but are necessary to obtain efficient control.

The three phase motor is of rugged construction, requires no commutator (general type), and enjoys the advantage that a greater continuous output can be secured within a given space than by any other form of motor. Another advantage of the three phase motor, which is of great importance on mountain divisions but unimportant on most divisions of trunk lines, is that "regeneration" on down grades is very easily accomplished. This latter point was a factor in the decision of the Great Northern Railway to employ three phase.

It might be stated that there are two results desired in regenerating, namely, to economize power and to secure more reliable and cheaper control of trains on heavy grades. The maintenance cost of air-brake rigging on mountain divisions is very heavy; also, due to certain limiting features in connection with air brakes when used to control heavy trains, especially long freight trains, on long grades there is a danger of train parting.

When regeneration is practised, the duty on the brake system is greatly lessened.

Three phase equipment is obviously unsuitable for motor car service—both the overhead construction and the motor characteristics militate against its use in the class of service handled by multiple-unit motor car trains.

Selection of System

It has been often said of trunk line electrification that "every situation is a study in itself," and doubtless this is largely true for electrifications embracing trunk line divisions of limited extent and character of service, and this is the rule in most of the electrifications up to the present, which are mostly tunnel or terminal problems. It is only when an electrification is planned to embrace numerous divisions of a trunk line and to take care of all classes of traffic that the problem of selecting a "system" becomes most general. It is thus evident that cost data relating to any given electrification must not be accepted haphazard as applying to any other conditions than those obtaining in the specific case. Analysis to the last degree is necessary for the rendering of proper conclusions.

THE SCIENCE OF LEATHER MANUFACTURE

K. D. Marlatt, '08

The manufacture of leather is one of the oldest arts known to mankind, and dates far back in the prehistoric ages. Relics which have come down to us from Palaeolithic times, together with the experiences of modern explorers, prove to us that agriculture is of more modern development than hunting, and as the hunters had—at least in certain climates—to wear clothing, it is only natural to deduce that they must have used skins of animals for this purpose. They must have found that when the skin dried, it became hard, except at the places where there was a great amount of fat upon it, and that there it remained soft; so that the next step was to cover it with grease before drying, and thus the first leather was probably made. Then it was found that smoke also had a preservative action, so that the skins were covered with grease when held in front of a fire, in order that the smoke could blow upon them. The North American Indians made their leather in much the same way. The next step was to dye the skins with berries and barks, and so they found this also preserved the skin, and therefore they started to treat the skins with infusions of bark or berries, and thus laid the foundation for all vegetable tannage.

We have many references made to leather in the early books. In the "Iliad", Homer refers to the making of leather by putting grease upon the hide. In the time of Abraham, boots and shoes are spoken of. Also a mummy of the year 4600 B.C., was found wrapped in

a quilt of tanned and dyed sheep skins. An old carving from Syria also shows men unhairing and tanning 5900 years ago. Even in these olden days they knew how to emboss the leather. The Romans also were great tanners, and then the Moors.[1]

To come to more recent times, in the reign of Queen Elizabeth an Italian doctor of her court, under patent from her, introduced Sumac tanning into England. Sumac now is used extensively in light leather manufacture. In the years 1605, 1606, 1067, laws were made in England controlling the tanning industry, and some were very strict; one was, that any tanner who was found selling leather, which had not been in tan for three years was imprisoned, whereas, to-day some tanneries tan the same kind of leather in as many weeks.

In the year 1865, Prof. Knapp tanned the first Chrome leather. This is a chemical tannage, and is more rapid than any vegetable tannage, and has almost superseded bark for tanning light leather, and is also used for tanning heavy leather.

In this paper I shall chiefly deal with the manufacture of heavy leather, according to the English method. Let us first consider the hide itself. (1) The supply; (2) Preservation; (3) The hide structure.

The Supply

In England there are three classes of hides; (1) Shorthorns (Scotch breed); (2) Herefords; (3) Lowlands, and for value they rank in the order they are given.

Then there is the continental supply, which may be divided into two classes, those from the hilly regions, and those from the lowland regions. The former are much stronger and firmer hides owing to being exposed to severe climatic conditions.

There are also the Chinese hides, which are dried; hides from Australia and kips from India; South American, Canadian and United States hides, of which the Packer hides are the best.

Preservation

There are many methods of preserving hides, but the two commonest ones are by salting and drying. In both cases the principle is the same, namely to extract moisture from the hide, for putrefaction can take place only in the presence of moisture. Salt in itself has only slight antiseptic action, but it absorbs the moisture from the hide. In drying, the same object is in view, but it is a rather dangerous method, for if the hide be not dried fast enough putrefaction will start, and the hide goes to pieces when soaked, and if dried too rapidly, the hides cannct be softened with a reasonable amount of labor. Phenol, arsenicus acid, salicylic acid, boracic acid, and several other chemicals are used as antiseptics.

The Hide Structure

A hide is formed of two parts:—

(1) Epidermis: (a) Upper layer, or horny layer, (b) lower layer

1. Professor H. R. Proctor.

or *Rete Malpighi*. (2) The Corium (a) The Epidermis has to the completely removed in liming, if not one gets bad grain and bad color.

The epidermis is of cellular structure, each cell grows and then breaks up into several small cells. The more nourishment they receive the more quickly they grow. They are forced flat as they approach the surface, and so change from the *Rete Malpighi* into the horny layer.

The upper layer of the epidermis is not attacked in liming, but only the lower layer, or *Rete Malpighi*. This soft mucous layer is attacked and dissolved thus the horny layer being separated from the corium comes off in unhairing. In sweating the bacteria liquefy the *Rete Malpighi*, and so the hair is loosened.

The corium is of fibrous, not cellular structure. The fibres do not increase as the cells of the epidermis do, nor does the hair ever enter the corium. The fibres on the flesh are in bundles and interwoven, but as they get nearer the grain side they become finer, until at the grain itself they are single fibres, and more tightly interwoven, the fibres lying in a parallel position. The hair grows downwards, and takes the epidermis with it (in the epidermally surrounded sac). The root takes up the nodules of lymph of the corium, and feeds on them. Each hair is pushed out by a new one every year. The nodules of lymph are the life of the skin and the food which builds up the whole body. The lymph is a colorless fluid. The skin is bound together by elastic fibres, sometimes spoken of as yellow bands; these are dissolved in liming, and so the hide plumps and swells. The hide contains numbers of globules of grease, and the coarser fibres are full of them.

The hide is permeated with interfibiller substance, which is gelatinous, and which gradually changes to fibres. Pigment cells are in the root of the hair, and dye the same, and each hair has at least two fat glands. There is a net skin between the corium and the meat proper, this is removed by fleshing.

The formula for hide substance is not definitely known, and is very complex, but it is taken as being the same as gelatine minus one molecule of water, and one accepted formular for gelatine is, $C_{76}H_{124}N_{24}O_{29}$ which is rather a formidable formula.

Leather Manufacture

The actual manufacture of leather may be treated under several heads:

(1) Soaking
(2) Liming
(3) Bating
(4) Tanning (English Oak Sole leather)
 (a) Suspenders (c) Dusters
 (b) Handlers (d) Layers
(5) Scouring
(6) Drying
(7) Finishing

Soaking

When the hides are taken to the Beam House, the first object is to get them back as closely as possibly to the condition they were in when taken from the animal's back. With this object in view they are put into soaks, which are large vats filled with cold clean water, and they are left for two or three days, and the water on them is changed several times, and as the object of soaking is to remove all the dirt, blood, salt, or other preservatives, it is necessary to use clean water; and another reason for this is that when a soak liquor is allowed to get old, bacteria develop, and these dissolve the hide substance, and you lose weight. Hide substance is also soluble in warm water, so it is necessary to use cold water in soaks.

In soaking dried hides, old soak liquors are sometimes employed, since owing to the activity of the bacteria the hides soften more quickly than in fresh water, but this is a dangerous practice, as, if not watched carefully, much hide substance is lost. A better method for treating dry hides is to use a little Sodium Sulphide, or Sodium Hydrate with the clean water for part of the time they are in soak, and end by running in a latticed drum.

Liming

When the hide is in the proper condition, it is removed from the soak, and fleshed, that is, the rough flesh is taken off either by hand, or machine, and it is then put into a lime. There are a number of methods of liming, but in sole leather they generally use from 7-9 lbs. of lime per hide, and lime for 8-12 days. The amount of handling they get varies in different yards. Or Sodium Sulphide may be employed, in which case the quantity of lime used, and the time are both reduced, We might divide up the liming of heavy leathers into three classes:—

(1) Sole leather
(2) Harness and Belting leather
(3) Dressing leather, carriage, automobile, etc.

(1) Sole leather requires a short sharp liming, that is to say you wish to get the maximum plumping in the minimum time, and so the limes are never allowed to get very old. However, you must not underlime or you get a cracky grain.

(2) Harness and Belting leathers must be more pliable, and you use more mellow limes, that is to say, limes which are a little older.

(3) Dressing leathers should be soft and pliant, and you use still more mellow limes, and never make up an absolutely fresh one. Lime is soluble in water only to a very limited extent, 2-3 oz., pure lime, to 1 cubic ft. of water, or 1 part lime to about 778 parts cold water; however, as the purity of lime runs from about 60%, 80%, or 90%, and also as lime gets used up, it is necessary for one always has to use a large excess. Lime is one of the very few substances that is more soluble in cold than hot water.

In liming, three actions take place, namely, bacteriological, chemical and physical.

The bacteriological section is the action of bacteria on *Rete Malpighi*, that is to say, the peptonisation. The chemical action is the dissolving of the peptonised *Rete Malpighi*, hair bulb, lymph, and grease which latter is converted into a calcium soap. The physical action consists in alkalinity of the limes swelling and plumping the hide, and splitting up the bundles of fibres held together by the yellow bands.

The first action is the alkalies swelling and plumping, and then the bacteria work down the hair, and hair sac, peptonising the *Rete Malpighi*, and hair bulb, which when peptonised is soluble in lime, and the epidermis, and hair can be pushed off.

In using lime, unhairing is possible only by bacterial action. That is to say, unless limes were exposed to the air no unhairing would take place, for in a sealed lime a hide will not unhair. In this and other respects, lime differs from sodium sulphide, one of the commonest depilating agents. A comparison might here be given.

Lime	**Sodium Sulphide**
(1) Dissolves *Rete Malpighi* and so loosens hair only by bacterial action.	(1) Dissolves *Rete Malpighi* without bacterial action.
(2) Dissolves the yellow bands by swelling and plumping hide.	(2) Same as lime.
(3) Does not dissolve hide albumen.	(3) Dissolves hide albumen slightly more than lime.
(4) Forms insoluble calcium soap with fats and greases.	(4) Forms soluble sodium soap with fats and grease.
(5) No effect on hair.	(5) Destroys hair.

Lime and sulphide work together, and give excellent results, for apart from the action of the lime and sodium sulphide alone, one also gets developed double sulphides of calcium and sodium which play an important part in liming and also sodium hydrate is developed and this latter has very great plumping power. Another method employed for depilating in Canada and the United States is sweating. This method is briefly as follows. The hides are hung in a sweat pit at a temperature of 75 degrees-80 degrees F., and the temperature is controlled by a jet of steam blown in at intervals or by water sprinkled into the pit from above, depending upon whether you wish the temperature raised or lowered, and so the hides are always kept moist. After 4-6 days the hides are unhaired. In this method the unhairing is almost entirely due to bacteria which attack the hide and peptonise the *Rete Malpighi*, and if left too long the bacteria attack the hide itself. Ammonia is developed by the decomposition of organic matter, and this also aids in the depilating. In this method the hide is not properly plumped, nor is the grease killed, and so it is necessary to treat the hides with acid before tanning.

After liming, the hides are unhaired either by hand or machine. The treatment of the hide from here on varies with the class of leather to be made

Generally speaking, sole leather and harness and belting leathers are usually delimed by acid, that is to say, the hides are put into a vat with water, which has been weakly acidified with one of the following acids, sulphuric, lactic, formic, acetic or boracic. They are usually left until the lime is nearly neutralized, and then they are skudded on a beam, or run in a drum with water, to wash out the dirt. In making dressing leather, on the other hand, the treatment is different, and here the hides are bated. That is to say, they are put into a paddle with an infusion of hen manure, and run on and off for one or more days.

The bate has two chief actions:

(1) It neutralizes the lime present.

(2) It produces a certain amount of liquefaction of the interfibiller substance, thus pulling down the hide, and giving it a more mellow and pliable feel.

The first action is due to acids, and the second to bacteria. These actions may be expressed in another way.[1]

(1) Action of organized ferments

(2) Action of unorganized ferments

(3) Chemical action.

Many artificial bates have been made, but none that I know of, give as good results as the natural bate.

From the above outline, the reader can gain some idea of the tremendous influence different bacteria have on the hide in the early stages of leather manufacture, and even to-day their influence is not completely understood.

From the beam house the hides go to the tan yard, and here the methods are so diverse, not only between the different kinds of leather, that is, between sole, harness, dressing, and belting leathers, but also as there are innumerable methods for the tannage of each of these classes, that in this paper I shall take for a good example, the tannage of English oak sole leather. But first I shall speak of some tanning materials. These are divided into two classes, the Pyrogallol and Catechol tans.

The pyrogallol tans are those which have a plumping effect upon the leather, due to the acid they form when they ferment. They also deposit what is known as bloom, but which is really ellagic acid. Leather tanned with a pure pyrogallol tan does not change color on exposure to light.

The Catechol tans are those which do not have a plumping effect on the leather, and they do not sour and develop acid. They do not deposit bloom, but instead a sticky resinous matter called "Reds." Catechol tanned leathers are affected by light.

There are also a large number of chemical reactions to distinguish these two classes.

Some of the commoner pyrogallol tans are:—

(1) Myrobalans, obtained in India, 27% to 39% tan, and chestnut, an extract made from the wood, containing generally 25% tan.

1. Dr. J. G. Parker.

(2) Divi Divi, Central America, 40% to 50% tan.
(3) Sumac, Italy and Sicily, 28% to 30% tan.
(4) Algarobilla, Chili and India, 45% tan.

Some common Catehol tans are:—
(1) Gambier, Singapore, Straits Settlements, 25% to 40% tan.
(2) Mangrove, West Africa and Borneo, 4% to 40% tan.
(3) Quebracho, South America, 20% tan (generally used as an extract).
(4) Mimosa, Australia and Natal, 32% to 42% tan.
(5) Hemlock, Canada and United States, 8% to 11% tan.

Oak bark runs from 12% to 14% tan, and is chiefly a catechol tan, but has certain characteristics of the pyrogallol class, and so is said to belong to both classes.

Valonia, like oak bark, also seems to belong to both classes, but is chiefly a pyrogallol tan. There are two kinds of valonia, namely: Greek, 26% to 30%, and Smyrna, 32% to 36%.

The Process of Tanning

The object of tanning is to convert an easily putrescible substance, namely, the hide, into an almost imputrescible substance, leather. In tanning there are three actions:—

(1) Chemical:—Coagulation of the gelatine.
(2) Mechanical:—Deposition of "Bloom" or "Reds."
(3) Physical:—Coloring and plumping of the hide.
(4) Tannage of English Oak Sole leather.

After hides are unhaired they are put upon a table and "Rounded," that is, cut into butts, bellies, and shoulders.

I shall only deal with the tannage of the butts, since the bellies and shoulders get much the same treatment, only do not get so much attention.

Suspenders

After deliming, the butts are hung from straps, or in some other manner suspended in the first of a series of several pits, usually about nine in number, the strengths of which increase steadily from 8 degrees Barkometer. The butts are handled out of the liquors every day, and every other day they are moved forward one pit. They are in the suspenders for three weeks.

Handlers

From the suspenders the butts are put into handlers, or a series of pits in which the butts are piled flat, one upon the other. The strength of liquors runs from 18 degrees Barkometer to 22 degrees Barkometer. They remain in the handlers for four weeks, but are handled every day or every other day. When the butts come from the handlers they are about 70% tanned.

Dusters

From handlers they go to what are known as dusters, which are a series of pits of different strengths, 23 degrees, 25 degrees, 27

degrees, 30 degrees Barkometer, and in each pit the butts are laid flat, and then sprinkled or dusted with oak bark, or oak together with some other material. The butts start in the weakest liquor, and remain in for one week, then they are handled to the next pit, and so on. As the butts lie in this liquor the "bloom" gradually becomes deposited upon them and slowly is taken up by the butt, and so weight is got into the leather. This bloom also has an important effect upon the wearing quality, it greatly increases it. It also tends to make the leather more waterproof.

From the dusters the butts go to the layers, where the butts are laid flat in the vat and each one covered with bark. There are generally seven of these:—

(1) 30	degrees	Barkometer,	and	they	remain	2	weeks.
(2) 32	"	"	"	"	"	4	"
(3) 35	"	"	"	"	"	4	"
(4) 38	"	"	"	"	"	4	"
(5) 40	"	"	"	"	"	4	"
(6) 48	"	"	"	"	"	4	"
(7) 50	'	"	"	"	"	4	"

In the layers we have much the same things happening, as in the dusters. First the tannage is completed, and the bloom is then deposited upon the butts, and gradually taken up by them.

But only the heavy butts go through all seven layers. The light butts go through only two, and the medium, four or five.

The chief material used in the tanning of the above leather is oak bark, this is put through a grinding machine, and cut and crushed up into small pieces; this ground bark is then put into large—usually circular—vats, called leaches, and the tannin extracted with hot water. It requires several changes of water to get all the tan out. It is the general custom to make the first extractions with a tan liquor, and then use hot water.

You can only get about a 35 degree Barkometer liquor from oak bark, therefore to get the last four layer liquors, it is necessary to use some Valonia, or some Myrabolans are also used. Roughly speaking, the liquor starts with the strongest layer, and then is gradually worked down the yard to the suspenders, and from there is pumped up to the leaches again and used over.

After the butts come from the layers, the adhering bark is brushed off, and they are quickly rinsed through a weak liquor, and then piled and let drip for two days. Then they are hung up in drip sheds, which are almost air-tight sheds, and allowed to partly dry and solidify, until they are in an India rubbery condition, then they are taken down and piled to heat, and then scoured.

Scouring

The object of this is to remove from the grain the "Bloom" that has been deposited on the butt in the layers. This used to be done by hand, but now it is done chiefly by machine. The butt is placed on a movable table, and worked under the arms of the machine,

which are fitted with stones and brushes, and a certain amount of water is put on the butt, and the bloom is worked out of the grain. The amount of bloom taken out depends on three things:—

(1) The pressure used,
(2) The angle of the stones,
(3) The amount of water used.

After scouring the butt is pinned or struck out, that is to say, the butt is stretched and the grain smoothed down as much as possible.

Finishing

After pinning the grain of the butts is wiped clean with a wet cloth. Then the water is wiped off, and the grain dried by rubbing with a piece of dry flannel, after which the butt is oiled, usually with cod oil, on the grain.

The objects of oiling are (1) to get a soft pliant grain; (2) to make a rather waterproof surface on the grain, so that most of the drying takes place from the flesh side, and so prevents the strong liquors from drawing up to the grain surface, and so spoiling the color.

After oiling the butts are hung up in a shed, and dried slowly until just showing dry upon the edges. They are then taken down, and piled and allowed to sweat and again pinned, and again the grain is wiped clean, dried and oiled, and the butts are hung up till partly dried. Then they are rolled (rolled on) under a light pressure, and then hung up and dried still more, until the color shows up, and are then again rolled (rolled off) under a heavy pressure, and then dried out and polished, and are ready for sale.

L. T. Burwash, M.E.

At the conferring of degrees in Convocation Hall on June 7th, 1912, L. T. Burwash, '96, should have been there to receive from the hand of the Chancellor the degree of Mining Engineer, having very successfully qualified for the same. His thesis entitled "The Development of Placer Mining in the Frozen Gravels of the Yukon," is a veritable masterpiece containing information the equal of which has not been compiled heretofore in the interests of the great Yukon.

A graduate in Mining Engineering with the class of 1896, and a student in post-graduate work in the following year, Mr. Burwash set out for the Yukon in the spring of '97 in the employ of the North American Transportation and Trading Co. as its civil and mining engineer. During that year his work included: a track survey of the Chilcoot Pass; a general report on the upper six hundred miles of the Yukon River, with reference to navigation and transfer points; a surface and underground survey of the company's entire holdings; a three months' location at Bonanza Creek in charge of placer operations; and a report on the Coal Creek coal properties with data relative to some fourteen miles of tram roads. The fall of '98 and the following winter were spent in placer operations.

In June, 1899, Mr. Burwash entered the employ of the Canadian Government in the Gold Commissioner's Department. Six months later he was placed in charge of the Stewart River district as mining recorder and performed, in addition, the duties of mining inspector and Crown timber and land agent. Remaining in Stewart River district until July, '03, during which time he acted as general inspector for the Federal Government, reporting upon new districts, timber and lands, and water for power and mining, he was then transferred to the Kluane district in the same capacity, where similar work was performed until it was, likewise, completed in October, 1905. Whitehorse district was the next in line for a like development, and occupied Mr. Burwash's attention for five years, the work being similar to that in the foregoing districts as regards

G. H. DUGGAN, '82

L. T. BURWASH, '96

lands, timber and water. The mining included extensive copper, silver-gold, antimony-silver and silver-lead development work.

In 1910 Mr. Burwash was appointed Government mining engineer, stationed in Dawson City. The work consisted mainly of reports on mining, timber and land values of new sections; reports on water for power; hydraulic flume, ditches and pipe lines.

During the whole period of his connection with the Government, an important part of his work has consisted in the interpretation and administration of mining, land, timber, water and coal laws, as provided by the Dominion Government to govern the Yukon and other organized territories.

A photograph of G. H. Duggan, '82, is also being reproduced here, it having arrived too late to accompany his biography appearing in the June number.

CONCERNING SCHOLARSHIPS

Dear Sir:

Though your appeal to the graduates concerning the research scholarships was for money and men, and neither opinion nor advice, I doubt not your interest in their views. I may venture, then, to survey this latest field in which the School man will toil.

Your scholarships have for their object the general good, through addition to the present fund of knowledge or new combinations of facts already known. It is a worthy and altruistic aim indeed. But, although this altruism may continue indefinitely, its continuance, if it does not depend, at least will be much encouraged by the attainment of definite results by your scholars. With your committee rests the responsibility of selecting men to carry out your ideas, and, therefore, on the means by which you propose to make this selection hangs the success or failure of the enterprise. So far as I understand the method of selection which you have adopted (after the determination of the subjects to be investigated) that candidate will be chosen whose academic standing is the highest, and whose employment in the interim since graduation has been with the best known firms. Not that this alone will be your yard stick. The folly of such a measure is obvious. But I believe that you will have no other, in most cases, and must, unconsciously perhaps, make use of it.

To maintain that honor students will not be given a preference, under the existing arrangement, is folly. It is not in human nature to be uninfluenced by the college record, especially as the appointment is made in committee with members of the University staff, who look upon such a record as the be-all and the end-all of ability. Though I have your assurance of impartiality, and though I recognize your good intentions. I can no more believe that your committee will be impartial than I can believe the average man capable of fidelity to his religion when called upon to put into practice its dictum that he shall love his neighbor as himself, when the party in question is on the next social floor, "going down."

That great academic and professional attainment can coexist with a dearth of constructive ability needs no demonstration. Witness the absence of any marked creative achievements among our graduates (though this is no proof that the talent is lacking). Yet it is by just such accomplishments that your selection will be determined. Here is a difficulty which to me seems grave.

Without the constructive faculty that can correlate the Calculus or the Logarithm with the mechanism of the planimeter and slide rule, or harness the pure science of biology to the menial work of sewage disposal, your scholarship can be little

better than a specialized post-graduate course, to which no one can be expected to subscribe, other than through his taxes. This question of temperament seems to me to have a large significance; men of meagre equipment, in their youth, such as Herbert Spencer, Edison or Paul Ehrlich, may accomplish more of real worth, in the long run, than those far above them in promise, if learning and station are the criteria. If your committee can devise a way of finding men of this stamp and can rescue them from the thraldom of commercial life, rich indeed will be the reward of your efforts.

Further, we may eliminate from our category of applicants the graduate of five or more years' standing. To such, unless of independent means, the scholarship is an impossibility. Such men are usually settled in life, and no prudent man, on whose labor the sustenance of a family depended, would forsake his permanent employment to gratify a desire for research. By this time, also, the student ardour of most of us has had time to cool to such an extent that our research possibilities could be represented by a digit in the fourth decimal place. Even should the graduate be master of some technical subject (from which in all probability he derives a livelihood) can the university offer the facilities for study that accompany the practice of his profession?

But let us assume that the appointment has been made, no matter to whom, but let the scholar be a recent graduate. Can we hope for any valuable additions to our knowledge to result from the work of such a tyro in the absurdly short period of a single academic year. The experience of every graduate in compiling his thesis will convince him of the hopelessness of the undertaking. Coupled with his disability is the disquieting fact that discoveries are expected of him. The eyes of the alumni are upon him, his position is a public one, and if he fails, as fail he most likely will, he is to be humiliated by the cancellation of the scholarship.

I can find no possible escape from the premise that results are necessary. Not only do I consider the self-regard of both alumni and scholar as factors of importance, but believe their egoism and altruism to be the warp and woof of the whole fabric. Let me quote from the "Wealth of Nations": "But man has almost constant need for the help of his brethren, and it is vain for him to expect it from their benevolence only. He will be more likely to prevail if he can interest their self-love in his favor, and show them that it is for their own advantage to do for him what he requires of them." This homely logic can only be interpreted to mean that success of the scholarship will follow success of the scholar.

Could your committee influence the university to establish fellowships, available for any graduate, which would give the holder, in exchange for a limited amount of tutorial work, a

reasonable use of the laboratories, free tuition, and about $500 per annum? One or several years under these conditions should enable a student to come to you with tangible evidence of ability, and a knowledge of his subject sufficient to go on with research without enacting a travesty on the word. An alternative would be to allow the student to continue his study at his own expense.

Under these circumstances your scholarship would assume the character of a prize: it would be an honor to hold the position; it would indicate in the holder a capacity for consistent effort and natural ability for research. Your scholarship could hardly ever get into the hands of the sponge variety of student who can only absorb, the variety which at present usually obtain such scholarships, through the mistaken idea that creative ability has other ear-marks than creation.

The future of the student you could easily assure in some way similar to that of the "Industrial Fellowships" of Prof. Duncan, of Kansas University, so well explained by him in a chapter of his work "Industrial Chemistry." For at the end of the student's tenure he finds himself in possession of special knowledge, perhaps a reputation; but he has lengthened his preparation for life a year or two, he has neglected to cultivate the gentle art of selling his services to advantage, and he is not one whit further ahead in the business of life. Now, by "future" I do not mean a berth on Easy Street, but, rather, after the example of Kansas University, that the alumni bestir itself in the student's interest and place him in a position in the industry in which he has worked, in order that he may continue to advance the knowledge of his chosen subject: for the alumni is far better able to successfully do this than the student. It would require but small exertion on your part, and would constitute a powerful inducement to undertake the scholarship work. But do not imagine that I mean to bait the student with any such inducement. As stated before, his qualifications I take to be some evidence of capacity for this work and only this. But having found your scholar he is too valuable a man to allow to drift off into other lines. Doing this would be akin to building a Titanic in order to cross the sea, and then turning her adrift at the conclusion of the first passage; it might get into the hands of those who could use it, but, ten to one, it would founder.

In conclusion, I may say my object is not to provoke discussion, but rather to offer what is of value in my ideas. The subject has interested me for some years, and no amount of argument only will alter my opinions; for I have yet to learn of a single great discovery that is the result, direct or remote, of a scholarship. Of the reason I assign I think you are aware. Put a truck horse on the track and the stable will seldom own the Plate. Now, scholarship awards are made on evidence of draughting ability, the man of worth takes precedent, rightly so

if you like, over him who can discover, but is good for naught else. (If you have read Isaac Newton's biography you will remember that he either could not or would not "work.") The result is consistent.

I can distinguish nothing about the "School" scholarships to indicate that they will fulfil their mission where similar scholarships fail, time and time again, or only partially succeed. And I am trying to suggest that you have means within your reach that may make the selection of a scholar less uncertain, not next year but right now.

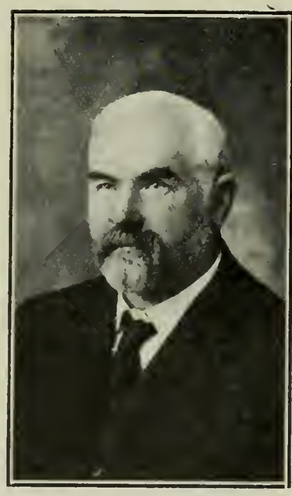
Yours very truly,
Eddie Current.

Toronto, July 15th, 1912

BIOGRAPHY

Jas. H. Kennedy, '82

It was just thirty years ago that the graduating class of '82, a trio of men who had spent three years in association with Dean Galbraith, at the time when the institution demanded their enthusiasm and received in full measure their co-operation, took to the field. Mr. Jas. H. Kennedy, one of this triumvirate, was born in Carlton county in 1852, and enrolled as a student in engineering in 1879 at the School of Practical Science. Upon leaving the old School he engaged as rodman on preliminary survey work for the Lake Superior division of the Canadian Pacific Railway from Pic River to Missanabie, and later in the year was appointed assistant engineer on the measurement of all rock work on Section " B " of the Canadian Pacific Railway for Manning, McDonald, McLaren & Co., a firm of railway contractors, who measured the line from Rat Portage sixty miles eastward. In the following year he was successively leveller, transitman, and assistant engineer in charge of the construction on the Lake Superior division, C.P.R., which was brought to completion in 1885. This work afforded him a great deal of valuable experience and success in revising location. In 1886 he was locating engineer for the same company between Woodstock and London, Ontario, and had charge of the construction of twelve miles of this branch. In the following year, under Mr. R. Adams Davey, chief engineer for the Temiscouata Railway, he located and built twenty-one miles of road from Lake Temiscouata to Edmundston, N. B., and in the following year located a line for the same rail-



way up St. Johns River from Edmundston to Fort Kent. Later in the same year Mr. Kennedy engaged as assistant engineer for the Montana Central Railway in laying track on the Neihart branch, and as locating engineer on the main line of the Great Northern Railway from the summit of the Rocky Mountains westward to Flathead Valley. Later he became resident engineer on construction until the completion of that division in 1892. After this he was assistant engineer in charge of the construction of about fifty miles of the Soo Line in Dakota, under the late W. W. Rich, who was then chief engineer.

Mr. Kennedy came east in '94 and engaged in private practice as land surveyor at St. Thomas, Ontario. Four years later, however, found him back in railway work again, this time for Mackenzie & Mann on surveys between the Stikine River and Teslin Lake. After the conpletion of this work, he surveyed a line in southern British Columbia from Penticton to Midway, a distance of eighty miles, and later located a fourth part of the branch. In the following year, 1899, he superintended considerable survey and prospect work for the British American Coal Co., and located a spur line from the Canadian Pacific Railway Crow's Nest line into the Coal Company's property south of the Crow's Nest Pass region.

In 1911, Mr. Kennedy was appointed chief engineer of the Vancouver, Victoria, and Eastern Railway, and constructed its line from Laurier, Washington, to Grand Forks, B.C. Two years later, during a cessation of the work, he revised the location of the Toronto & Niagara Power lines from Hamilton to Grimsby for the late Mr. W. T. Jennings. The Vancouver, Victoria and Eastern Railway work was resumed in May, '04, and from that time up to the present, Mr. Kennedy has been continuously employed on its construction work, until 1909, as chief engineer. At that time the company absorbed a number of smaller lines, and Mr. Kennedy assumed the responsibilities of the office of assistant chief engineer of the whole organization. During his connection with this company some $17,000,000.00 have been expended upon surveys and construction alone. The last division of the road, seventy-eight miles in length, to connect the Kootenay country with the coast, is at present in the process of construction. The part of this line on the western slope of the Hope Mountain is, in all probability, the heaviest construction yet undertaken in British Columbia.

Mr. Kennedy's labors in bush and field have not monopolized his time to the detriment of his knowledge of general engineering accomplishments and advancement. His engineering knowledge extends far beyond the limits of railway construction and operation. In 1887 Mr. Kennedy was granted his Ontario Land Surveyor's certificate. He has been a member of the Canadian Society of Civil Engineers since '93, and of the American Society of Civil Engineers for the last twelve years.

J. J. O'Hearn, '09, and D. D. McAlpine, '09, are with the Canadian General Electric Co., at their head office in Toronto.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published every month in the year by the University of Toronto Engineering Society

SUBSCRIPTION RATES

Per year, in advance	$2.00
Single copies	20

Advertising rates on application

Address all communications:

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

EDITORIAL

CONCERNING SCHOLARSHIPS

On another page a letter appears from one of our graduates giving his views upon some phases of the research scholarship movement. The writer strikes an emphatic chord when he states that much depends upon the selection of the scholar. More depends thereon than anyone is wont to aver at this early stage. But among the proper qualifications and other idiosyncrasies of the candidate as he defines them, he lays undue stress upon the attainment of honors during the University course, as an asset of great importance to the candidate's chances of being successful in his application.

An honor standing is, and should be, the ideal of every undergraduate. The mark is a very distinctive one in the Faculty of Applied Science and Engineering, showing that a greatly desired degree of intelligence has been displayed throughout the

term and in the examination hall. But even the student is well aware that the road to success in his chosen profession is none the less susceptible to tedious problems that again and again require his best effort. He does not lean for support upon his class standing. As applied to research work, if it signifies anything at all, this honor standing implies that the applicant has more comprehensively grasped the subject matter as laid down by the curriculum than the showing made by the man of pass standing indicates. If the subject chosen for research is one bearing directly upon the work which formed the basis of his excellent standing at examination, one naturally expects the latter to be decidedly in his favor. In such a case reference would likely be made to it.

But it is much more likely that the subject for research is far remote from the work covered in the University course. Then an explicit description of what he proposes to do, backed up by an exhaustive enumeration, lending itself to clear reference on the part of the examining committee, of things already known about his problem, and his intelligent views of the possibilities his preliminary study of the subject has brought out, these are of next importance to the subject itself. Of course, this does not conclude the investigations which the committee must carry on before making an award. They must have reason to have implicit faith in the man himself and to value his intentions. They do not resort to the class list for this, however.

Nor need the University staff be charged with any unlike methods of selection. Although not personally acquainted with all characteristics of their students, the instructors do not fail to use their powers of observation and readily discern in a man the qualities which mark him of investigative spirit or otherwise. In four years' association they know a student's qualifications for engineering better than he knows himself. Moreover, they know the examination record to be a poor criterion of ability and are inclined to take particular interest in the man who views the class list with an air of disdain for five-sixths of the academic year and busies himself in the broader channels of observation that are open to him.

SCHOLARSHIPS THAT ARE NEEDED

When the writer refers to the adoption in Kansas University of what is there known as "Temporary Industrial Fellowships," he speaks of one of the foremost progressive movements of the age. Did Kansas lower her status as a University by unlocking her laboratories to aid the manufacturer in converting wasteful methods into scientific enterprises? The answer is in the success of Professor Duncan's undertaking. It defines Kansas University as an institution devoting its store of scientific resources to a useful purpose that replaces rule of thumb by its own product—

established scientific principles, utilitarian in character, and baneful towards universal waste.

Too many manufacturers have gone to a great deal of expense, with no important results accruing therefrom, in endeavoring to improve methods of manufacture, traditional processes, wasteful and inefficient. They should be better aware of the value the laboratories of the University, with unlimited possibilities in the way of scientific knowledge, extensive apparatus for the investigation of the untried, and men with whom it has thoroughly familiarized these resources. A better acquaintance would eliminate many drawbacks with which their organizations must contend. The sooner the University on its part hearkens to the special needs of industry the sooner it will serve its country to the best of advantage.

Referring again to the letter, although the writer is not prone to look optimistically upon the prospect of fruits from our own research scholarships at present being put under way, he has summed up many valuable points that will clarify in the minds of all concerned and ultimately establish more confidence where forebodings may heretofore have prevailed in the graduate body. We invite the opinions of others for the same purpose.

SCHOLARSHIP APPLICATIONS

It is expected that two scholarships will shortly be awarded by the University of Toronto Engineering Alumni Association, and that all preparations will be made for the successful candidates to begin their preliminary work, before the term opens in October. The interest that has been taken by the graduates in this movement pronounces it one of the greatest that any graduate body has ever undertaken for the benefit of science in general and a few of its members in particular. Nor has the movement been considered lightly by those in a position to undertake the work of experimental research. Quite a number of applications were received and they are undergoing fullest consideration at the present time by the scholarship committee and by the members of the staff concerned. The absolute necessity of careful selection and proper judgment in the awarding of the first scholarship has determined the committee to leave no part of their duty undone.

The applications themselves are for the most part well drawn up, displaying a conception on the part of each applicant of all that has already been done on his subject, and a realization that he is undertaking, if accepted, a very important work.

No definite awards can be made for some time yet, but the next issue of "Applied Science" will contain information as to what has been done to date.

A. W. Youell, '10, is with the Canadian Ingersoll-Rand Co., at Sherbrooke, Que.

OBITUARY

Readers of "Applied Science" have been shocked to hear of the sudden death of Cecil B. Smith, Ma.E., senior member of the well known firm of Smith, Kerry & Chace, and of a number of subsidiary power organizations operating throughout Canada. Mr. Smith had a world-wide reputation in the field of hydro-electric development, and the engineering profession has lost one of its foremost civil engineers. Mr. Smith graduated in 1884 from McGill University, receiving the Governor-General's medal. His prominence in the work of technical societies is universally known.

The School is unfortunate in losing one of its prominent graduates, in the person of Frank T. Conlon, a graduate of '02, who passed away on July 10th, after a long illness. For some time previous to his death Mr. Conlon was a member of the engineering staff of the Welland Canal. When enrolled in the School he was a member of the class in mining engineering.

The article entitled "The University of Toronto and the Mining Industry,'" the first part of which appeared in the June issue of "Applied Science," will be continued in the August number. The writer, Professor Haultain, was out of the city on a business trip while this issue was being made up.

The Vulcan Fellowship in Engineering founded by the Vulcan Boiler and General Insurance Co. in the Victoria University of Manchester, is open to graduates of this Faculty. The Fellowship is of the annual value of £120, and is for research in mechanical and electrical engineering. "Applied Science" will give further information to any one interested.

The Canadian Committee of the International Road Congress, has recently been formed with a view to represent the Dominion at the convention in London next year. Dean Galbraith is president of the newly-organized committee.

C. W. Dill, a member of the civil engineering class of '91, and a member of the firm of Dill, Russell & Chambers, contractors, recently received an appointment to the Board of Highway Commissioners of Saskatchewan.

If readers who have not received binders for Volume V. of this journal, November, 1911, to April, 1912, will notify us at once, their orders will receive attention. These binders are sent free to all paid subscribers.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 24 TORONTO, AUGUST, 1912 New Series Vol. VI, No. 4

THE UNIVERSITY OF TORONTO AND THE MINERAL INDUSTRY

By H. E. T. Haultain

Professor of Mining Engineering in the University of Toronto

(Part II.)

Mineralogy is the science of minerals, and geology is the science of rocks. The basis of the mineral industry is minerals, and minerals are found in rocks. Hence, to the popular mind the syllogism is complete; the shortest step is to go to geology and mineralogy for that enlightenment and for that philosophy which will aid the mineral industry. Thus the two handmaidens of the profession of mining engineering are mistaken for the mistress.

In 1856, Dr. E. J. Chapman was appointed Professor of Mineralogy and Geology in the University of Toronto and, at that time, the University stamped its approval of the teaching of mineralogy and geology in advanced education.

The first curriculum of the S. P. S., published in the prospectus of the first session, 1878-79, was as follows:—

(1) Department of Engineering

This course is intended to qualify students to prosecute the various professional branches of engineering. During the first two years the course is for the most part common to the students of all three branches (Civil, Mechanical and Mining Engineering). In the course of the second year, however, the student is required to select such one of the three branches which he intends to specially pursue, and the studies of the third year are arranged in conformity therewith.

Subjects of the First Year

1. Mathematics—including Plane Trigonometry and Analytical Conic Sections.
2. Mechanics—Elementary Statics and Calculations of Framed Structures.
3. Drawing—Freehand, Linear and Elementary Projection.
4. Surveying—Chain and Compass. Plotting from Notes.
5. Construction—General Principles and Foundations.
6. Elementary Chemistry.

Subjects of the Second Year

A.—Common to all Three Branches.

1. Mathematics—Differential and Integral Calculi and Spherical Trigonometry.
2. Drawing—Freehand and Descriptive Geometry.
3. Physics—Statics and Dynamics, Hydraulics and Optics.
4. Mensuration.
5. Elementary Mineralogy and Geology.

B.—Special Subjects for each Branch.

Civil—
- Geodesy and Astronomy.
- Surveying—Theodolite, Level, etc.
- Construction—Roads and Railways.

Mechanical—
- Machinery.
- Designing.

Mining—
- Crystallography.
- Palaeontology.
- Determinative Mineralogy.
- Blowpipe Analysis.
- Surveying.

Subjects of the Third Year

Civil—
- Surveying—Railway and Canal Surveying, Hydrography.
- Freehand Drawing.
- Applied Mechanics—Resistance of Material Structures in Stone, Wood and Iron.
- Hydraulics—Water Supply, Drainage.
- Mineralogy—Determination of Minerals. Minerals of Ontario.
- Metallurgy—Manufacture of Iron and Steel.
- Construction—Bridges, Canals and Harbours.
- Steam Engines.
- Experimental Physics.
- Designing and Estimates.

Mechanical—
- Physics—Mechanical Theory of Heat

Freehand Drawing.
Applied Mechanics—Resistance of Materials. Structures in Stone, Wood and Iron.
Machines—Proportions and Parts.
Motors—Steam and Hydraulic Engines, and Pumping Machinery.
Mineralogy—Determination of Minerals. Minerals of Ontario.
Metallurgy—Manufacture of Iron and Steel.
Experimental Physics.
Designing and Estimates.

Mining—

Assaying and Ore-dressing.
Crystallography, Geology and Palaeontology.
Mining—Geology.
Mining Processes Employed.
Mining Machinery.
Motors—Steam and Hydraulic Engines, and Pumping Machinery.
Metallurgy.
Chemistry.
Experimental Physics.

From this it will be seen that Elementary Mineralogy and Geology took their places in all branches of engineering in the first year and the Determination of Minerals and the Minerals of Ontario in the third year.

In addition to the course in Mining Engineering there was a department apparently closer to the Mineral industry.

(2) Department of Assaying and Mining Geology

In this department the student is fully prepared in all the methods of analysis necessary to render him a competent assayist. He is also qualified to survey and report upon the value of mineral lands.

Subjects of First Year

1. Elementary Mathematics, including Mensuration and Plane Trigonometry.
2. Elements of Natural Philosophy, including Mechanics, Hydraulics.
3. Inorganic Chemistry.
4. Elementary Biology.
5. Elementary Mineralogy and Blowpipe Practice.
6. Physical Geography, Palaeontology and Geology.
7. Drawing.

Subjects of Second Year

1. Higher Mathematics, including Spherical Trigonometry, etc.
2. Chemistry, with laboratory practice in Qualitative Analysis.
3. Blowpipe Analysis and Determinative Mineralogy.

4. Geology and Economic Minerals of Canada.

5. Surveying and Levelling.

Subjects of Third Year

1. Quantitative Chemical Analysis.

2. Metallurgy.

3. Assaying.

4. Study of Metallic Veins and other Mineral Deposits, Mining Calculations, Examination of Mineral Lands.

It is to be noted that, after this course, the graduate was alleged to be qualified to report on the value of mineral lands, a fallacy from which we are now trying to escape.

This curriculum in Assaying and Mining Geology remained practically without change until it was abandoned in 1892. In fact the only change that was made appears to have been in the substitution of the word "assayer" for "assayist" in 1882. I can find no record of any student having graduated in this course.

In 1892, Mining Engineering, which for several years had been included as a sub-division of the Department of Civil Engineering, appeared as a separate department. The work of this new department differed from the course in Civil Engineering chiefly in the addition of more Chemistry, Mineralogy and Geology, together with some Mining Metallurgy, Ore-dressing and Assaying. Drawing and some other subjects were squeezed, and Hydrographic-survey and Drainage, Sewerage, etc., were dropped to make room for the mining subjects. At this time, also, was instituted an additional and optional fourth year leading to the degree of B.A.Sc. which has been referred to in Part I of this series. For the students in Mining Engineering the subjects of study in the fourth year were Mineralogy, Geology, Metallurgy and Assaying. In connection with that it is interesting to note that there was at this time no professor or lecturer in mining, but there was a professor in Mineralogy and Geology, and a professor of Metallurgy and Assaying, the latter of whom became professor of Geology at a later date. In regard to the details of the curriculum and the amount of time devoted to the different subjects, the Calendars are not explicit or specific until a later date; but, apparently this curriculum remained much the same for many years, there being from time to time, some increases in the work in Mineralogy, Geology and Chemistry.

It is of importance to note that in the third year curriculum under the heading of Mineralogy and Geology the sub-divisions are, Economic Geology, Palaeontology, Blowpipe Analysis, and Determinative Mineralogy, *Metallurgy, Mining, Ore-Dressing, Assaying* (the italics are mine); and these four last subjects remained classified in the calendars under the heading of Mineralogy and Geology for ten years or more. As further evidence of the relative position of men and subjects there appears in the Calendars from 1896 a classification of subjects and instructions from which this is taken.

Subject	Instructors
Mineralogy and Geology Palaeontology Metallurgy and Assaying Mining and Ore-dressing Milling German.	A. P. Coleman, M.A. Ph.D., Professor. G. R. Mickle, B.A., Lecturer. * * * Demonstrator.

The calendar for the session 1891-92 states that a lecturer in Mining Engineering was to be appointed before October 1, 1891. Apparently this idea was dropped for the time and A. P. Coleman, M.A., Ph.D., was appointed Professor of Assaying and Metallurgy on the staff of the Faculty of the School.

In 1894 Mr. G. R. Mickle was apppointed lecturer in Mining and for some years gave his time for part of the session only.

In 1901 the title of Dr. A. P. Coleman was changed to Professor of Geology. In 1902, T. L. Walker, M.A., Ph.D., was appointed Professor of Mineralogy in the Faculty of Arts of the University. In 1905 Mr. G. R. Mickle was appointed Professor of Mining. In 1907, W. A. Parks, B.A., Ph.D., was appointed Associate Professor of Geology. In 1908 Professor Mickle resigned to take up the position of Mines Assessor with the Ontario Government, and I was appointed Associate Professor of Mining, which title was changed to Professor of Mining Engineering in 1910. Mr. Geo. A. Guess was appointed Professor of Metallurgy in January, 1912.

Professor Chapman had established blowpipe and assaying laboratories at an early date and also collections of minerals and geological specimens. In 1896 a stamp-mill and ore-dressing appliances were installed, along with roasting furnaces and other metallurgical apparatus. Ten years later the fine, large Chemistry and Mining building on College Street was built. In this Professor Mickle had secured excellent accommodations for assaying laboratories, seven rooms in all, a large room for a metallurgical laboratory, and a fine separate building, seventy feet square, to accommodate the machinery for the mechanical treatment of ores. This was a magnificent step forward and the very greatest credit is due to Mr. Mickle for securing it.

I have dealt with the history of the staff and with some phases of the curriculum, and have touched on the growth of the laboratories. I should like to deal at length with the history of the time table and the subdivision of the work of the session among the different subjects.

This is a matter of very serious import. The most difficult result to achieve and at the same time the most important, is a proper balance of subjects. In the School this phase of the problem has been considered paramount. There have been many optional courses, but each course has been carefully balanced in its entirety by those in control. The student can take his choice of courses but he cannot take his choice of subjects. The engineer must be essentially a man of balanced education. This can very easily be understood when we consider what the effect would be if the subject

of mathematics were allowed to run to extremes, if the academic mathematics were developed, not to the exclusion of the practical applications, but to such an extent as to destroy the rational perspective. A true perspective is probably of more importance to the young engineer than the inclusion or exclusion of some valuable practical subject. I believe that the great strength of the School has been in the balance attained in its Engineering courses, more particularly in Civil Engineering. The course in Mining Engineering seems to have been somewhat out of the fold and to have travelled by itself, and there has not been preserved to it the balance that obtains in the other courses. The Calendar of 1908-09 gives the course in Mining Engineering as follows:

Subjects for Instruction

I. Year

Lecture Courses

Algebra	Descriptive Geometry	Dynamics
Plane Trigonometry	Surveying	Elementary Chemistry
Analytical Geometry	Statics	Elementary Mineralogy

Laboratory Courses

Drawing	Surveying	Practical Chemistry	Determinative Mineralogy

II. Year

Lecture Courses

Calculus	Dynamics of Rotation	Optics
Spherical Trigonometry	Strength of Materials	Hydrostatics
Descriptive Geometry	Engineering Chemistry	Metallurgy of Iron and Steel
Surveying	Organic Chemistry	
Lithology	Geology	

Laboratory Courses

Drawing	Photography	Practical Chemistry (Quantitative)
Surveying	Hydrostatics	Determinative Mineralogy
Optics	Practical Chemistry (Qualitative	Lithology

III. Year

Lecture Courses

Descriptive Geometry	Theory of Construction	Mining and Ore Dressing
Surveying and Levelling	Engineering Chemistry	Economic Geology
Thermodynamics	Analytical Chemistry	Dynamic and Structural Geology
Hydraulics	Metallurgy	Heat
Electricity	Ore Deposits	

Laboratory Courses

Drawing	Heat	Determinative Mineralogy
Surveying	Practical Chemistry	Crystallography
Assaying		

There was at this time no course in Metallurgical Engineering; the course in Mining Engineering was supposed to prepare for both

careers. On the face of it this looks like a well balanced course, but an analysis of the distribution of time shows as follows in the course for the diploma in Mining Engineering:

Mineralogy, including Blowpiping and Determinative Mineralogy and its allied subjects of Crystallography and Petrography	162 hrs.
Geology	100 hrs.
Metallurgy of Gold, Silver, Lead, Copper, Nickel, etc	25 hrs.
Mining and Ore-dressing	25 hrs.

These figures represent the total time given to these subjects in the complete course for the diploma.

The subjects of the fourth year, which is an optional year, leading to the degree of B.A.Sc., are—Mineralogy and Geology, Metallurgy and Assaying.

In the course of three years leading to the Diploma in the Department of Mining Engineering the total time allotted to Mining was thirteen hours against 262 allotted to Mineralogy and Geology. In the fourth year of this course there was no time allotted to Mining, Mineralogy and Geology divided the year with Metallurgy and Assaying. As a further evidence of the peculiar balance of things, the Calendar shows that in 1908-09 there were in the Departments of Mineralogy and Geology two professors and an associate professor and a lecturer, while in the Department of Mining there was only an associate professor, who was responsible also for the Metallurgy.

The Government blue book dealing with University affairs shows that for that session the appropriation for the departments of Mineralogy and Geology, including salaries, supplies and apparatus, was the sum of $18,740; and for the Department of Mining, which includes Metallurgy, the sum of $5,004.

Mineralogy is the science of minerals and Geology is the science of rocks. The basis of the mineral industry is minerals, and minerals are found in rocks. The attitude of the University of Toronto was to look to Mineralogy and Geology for that enlightenment and for that philosophy which should aid the mineral industry.

(To be continued)

REGINA ENGINEERING SOCIETY

On August 1st, the Engineering Society of Regina, held a meeting which had been postponed several weeks previous, owing to the devastation of the cyclone which visited the city on July 1st. Mr. P. Gillespie of the Department of Applied Mechanics, University of Toronto, addressed the meeting on "Re-inforced Concrete Columns." Mr. H. S. Carpenter, acting deputy Minister of Public Works for Saskatchewan, presided. A vote of thanks was moved by Mr. A. J. McPherson, Chairman of the Saskatchewan Highways Commission, and seconded by Mr. L. A. Thornton, City Commissioner for Regina.

Architectural Drawing
in the
University of Toronto

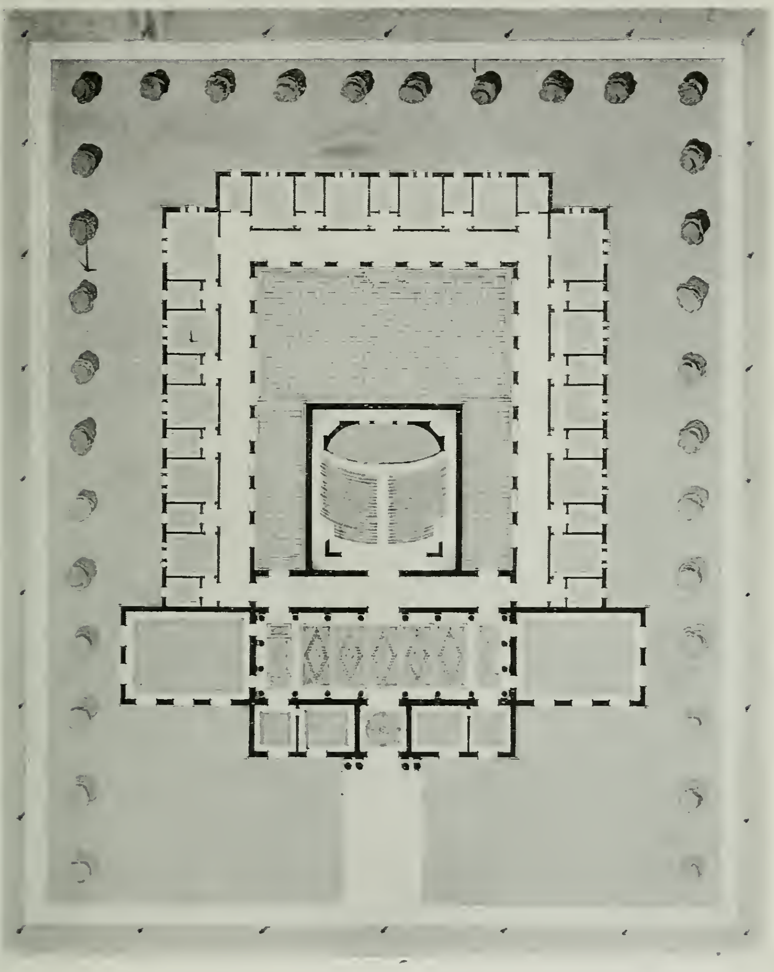
A Few Examples of Undergraduate Work During 1911-12

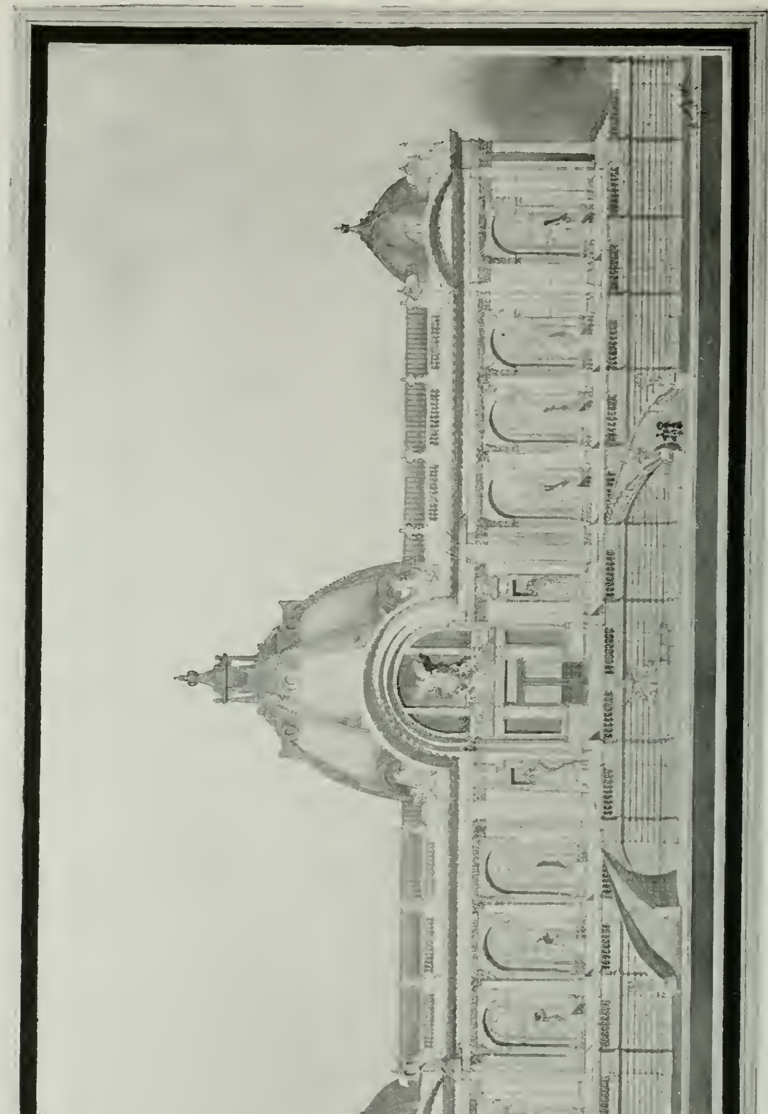
THE plate on the opposite page represents a design for a Provincial School of Music

BY

R. S. McCONNELL,

a third year student in the Department of Architecture, 1911-12





THE reproduction opposite is a representation of Le islative Buildings for a Canadian Province

BY

J. H. CRAIG,

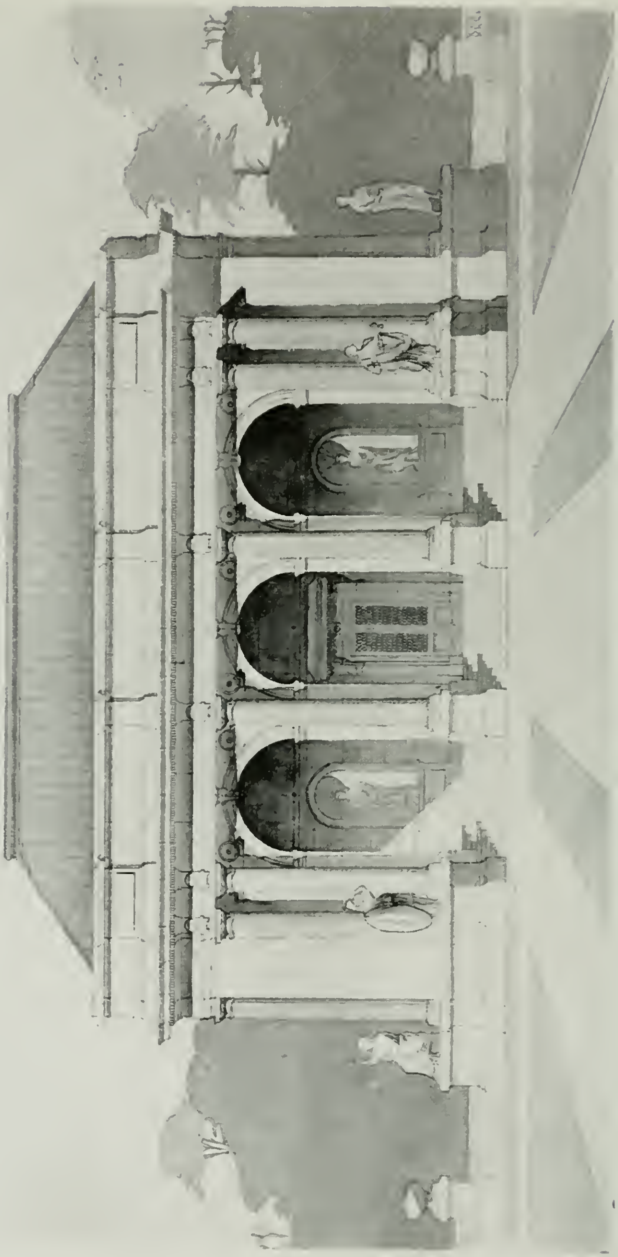
last year a fourth year student in Architecture, University of Toronto; now a member of the architectural firm of Craig & Madill Toronto.

REPRESENTING a design for Parliament Buildings drawn

BY

H. H. MADILL,

a fourth year student last year in the Department of Architecture, University of Toronto.

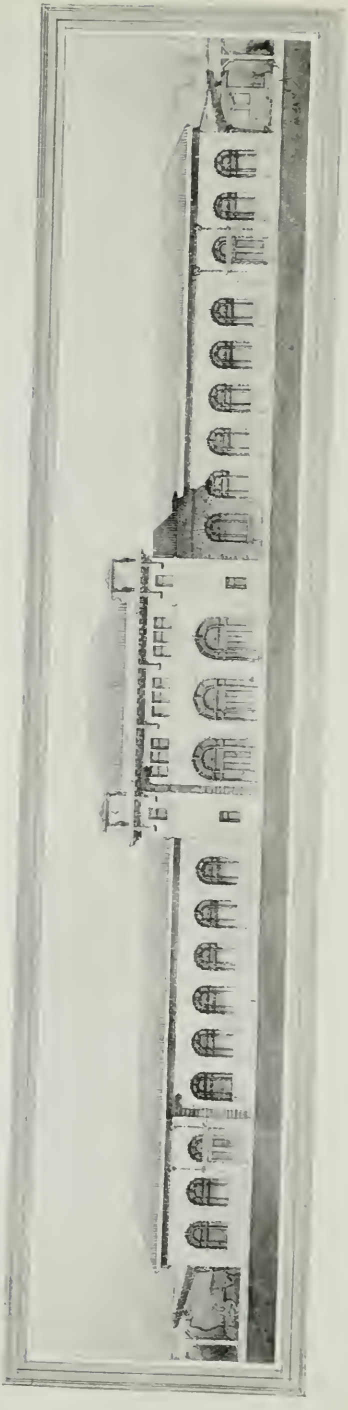


THE drawing on the opposite page was executed

BY

A. C. WILSON,

a member of the second year in Architecture, 1911-12, University of Toronto, and is a design for a Museum.

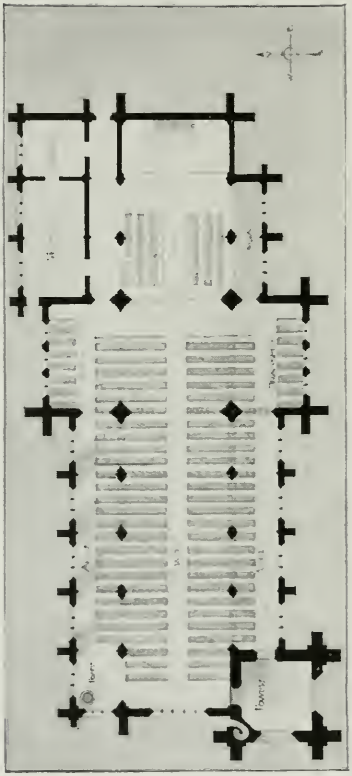


A TERMINAL Railway Station as designed

BY

H. H. MADILL

last year a student in the fourth year in Architecture University of Toronto. Mr. Madill is now a member of the architectural firm of Craig & Madill, Toronto.



A DESIGN, in plan, for a Church

BY

L. C. M. BALDWIN

of the third year class in Architecture, University of Toronto 1911-12.

LOCOMOTIVES—STEAM VERSUS ELECTRIC

By R. V. Macauley, B.A.Sc.

A great many of the features attending present day railroad operation are due in reality to certain characteristics of the steam locomotive. Under electric operation, sweeping changes in methods of conducting transportation are often either necessary or advisable. It is therefore necessary in arriving at intelligent conclusions regarding the advisability, or otherwise, of trunk line electrifications under different conditions, to have an intimate knowledge of the characteristics of steam and of electric power, as applied to traction work.

Steam Operation

Physical Characteristics of Steam Locomotives

All traffic on steam railroads is handled by means of steam locomotives. These locomotives, although of diverse types designed for the different service conditions, have many characteristics in common, which are mainly due to certain limitations imposed upon them. Briefly stated, the characteristics of the steam locomotive result from the fact that the locomotive must be a self-contained power unit, having its own coal and water supply, boiler and engines, mounted on trucks and moving over a track having a gauge of 4 feet 8½ inches, at various speeds up to 60, and in extreme cases to 70 and 80 miles per hour.

Locomotives use high grade bituminous coal. Coal handling plants must be located at frequent intervals along the line. The water supply is obtained from various sources, such as lakes, rivers and wells, along the route; water stations must be located at frequent intervals along the line. Where water is extremely bad, water treating plants must be used at each water station affected. To carry the coal and water supply, a "tender" must be hauled to accompany the locomotive proper.

Compact boilers, universally of the "fire-tube" type are used. High steam pressures (150-200 pds.) are employed to secure capacity; large radiation losses result, especially in cold weather. The boiler must be worked hard to get the greatest capacity, hence economy of coal suffers. Forced draft is obtained by exhausting from the engines through the stack.

Two engines must be provided—one for each side. In most cases, two simple engines are used. These engines must run non-condensing and operate with several pounds back pressure (to produce forced draft), hence steam economy is low. The engines drive the wheels by means of connecting rods to pins on the outside of the drivers, so that bearings on driver axles, which support the greater part of the locomotive weight, must be located between the driver wheels.

Operating Characteristics

The steam locomotive is essentially a constant power machine, this power being determined by the boiler capacity. The loco-

motive is capable of continuous operation at any speed up to the maximum, but the maximum speed in a given case depends both upon the length of the train and the grade of the track. It automatically slows down when ascending a grade, so that actual horse power developed does not vary greatly at different speeds. Otherwise expressed, a steam locomotive can exert its maximum draw bar pull at starting and at very low speeds, but as the speed is increased, the draw bar pull must be decreased.

The capacity that can be obtained in a single locomotive is limited for various reasons, and capacity beyond this practicable limit is obtained by double heading or by the use of Mallet articulated compounds—the latter being used almost exclusively for low speed, heavy grade service and short hauls.

Operating conditions require that a steam locomotive be "fired-up" (an operation requiring from 500 to 1600 lbs. of coal depending upon size of locomotive); kept standing a variable time at full pressure awaiting orders or train; then the "run" is made; after which the locomotive is sent to the round house where fire is drawn, hot water blown off, and tubes cleaned for the next run. This cycle of operations is manifestly hard on the coal pile, besides requiring much idle time, and labor.

Effect of Locomotive on Track and Bridges

Steam locomotives are destructive to track mainly for the two reasons following: First, because there are heavy reciprocating masses, connecting rods, and crank which can be balanced by a counterweight at only one speed and somewhat imperfectly at that. At other speeds there is an unbalanced centrifugal force which has a tendency first to raise the wheel from the rail and then to hammer it down upon the rail. This action is known as "track pounding." Second, because the pressures of many tons acting alternately on the pistons of the respective cylinders, which are widely spaced, and thus give great leverage, result in "nosing" from side to side Nosing of engines is a most serious characteristic as it results in rail loosening and spreading. The above two effects are of interest, not only in track maintenance and safety, but also in bridge design and safety. They also produce destructive strains in the frame of the locomotive itself.

The seriousness of this aspect of steam locomotive operation is emphasized by the report of 20 broken rails after a single trip (several years ago) of the Pennsylvania's "18 hour limited," New York to Chicago—this run being over a high class track and roadbed.

Steam locomotives, by reason of their unfavorable operating conditions, some of which have been referred to, and by reason of the severe strains set up in the locomotive frame, by boiler strains, nosing, bumping, etc., require numerous repairs and renewals of an expensive nature. The maintenance of steam locomotives demands extensive round houses with their complement of labor. The maintenance and repair cost of steam locomotives constitutes one of the chief items of expense in railroad operation.

Electric Operation

With electric traction there are two different methods of conducting transportation service. First, by the use of electric locomotives in a similar manner to that in which steam locomotives are used, that is, in hauling trains of freight or passenger cars. Second, by the use of motor cars in "multiple-unit" trains.

Most of the characteristics of electric locomotives and motor cars result from the methods employed for receiving power electrically and developing mechanical power.

Electric locomotives and cars (in three systems considered) receive their power through a contact system of electrical conductors from a central power station. The different systems of "working conductors," and the different kinds of motors used were briefly described in my article entitled "Electric Traction and its Progress," in the July number of Applied Science. Electric motors have a rotating element which develops mechanical power. The torque exerted by this rotating element is uniform (single phase motor has pulsating torque—but this is not serious at frequencies above, say, 15 cycles).

Motor Control

The motors require some system of control for varying the speed; the different methods of control were treated in the article mentioned above. One peculiar possibility with electric control is the "multiple-unit" system of operation. By this system it is possible to operate any number of motor units in "multiple" from the head of the train and in such a manner that each motor takes its proportionate share of the total load. This system is applied both to locomotives and to motor cars.

As applied to electric locomotives, the multiple unit system makes possible the concentration of very great tractive power, and makes it practicable by giving each locomotive an equal division of load, while requiring only one operating crew. As applied to motor car trains, this system permits of the application of great power to the axles throughout the train, and thus permits of the utilization of any desired train weight (up to the limit--when every axle is equipped) for driving adhesion at the rails; it is obvious that this makes possible very high rates of acceleration and consequently high schedule speeds in a service where stops are frequent—such a service as is required in suburban and other local passenger operation.

Operating Characteristics

Electric locomotives and cars draw their power from a large power station whose capacity is very great. The motors on the trains are able to stand very great overloads for short periods, while the continuous power output which it is permissible to develop is determined by the heating of the motor and in some cases by the commutation.

As before stated there are two methods of conducting service, namely, by locomotive trains and by multiple unit motor car trains. Each method possesses advantages for different classes of service. In general, electric traction methods tend in America to the use of multiple unit trains, for all short runs and local services. Electric locomotives are employed only where necessary, that is, for long express runs where cars must go beyond the electric zone, for special freight service such as heavy grade pusher and tunnel work and for terminal shunting.

Effect of Locomotives and Cars on Track, Road and Bridges

When the first development of electric locomotives began, it was thought that, "the characteristics of rotary motion and uniform torque possessed by the electric motor made its application to a locomotive a simple matter, and removed one of the chief defects of the steam locomotive, namely, the unbalanced reciprocating weights and unsymmetrical turning effort, which were held to be destructive to track."

Experience soon showed however, that the electric locomotives as designed were very hard on track, particularly at curves. There were two main reasons: first, excessive non-spring-borne (or "dead") weight per axle; second, low centre of gravity.

Since the large railroad companies have adopted electric locomotives, it is a notable fact that there has been a decided improvement in electric locomotive design.

A great number of tests have been made (notably by the Pennsylvania Railroad Company) and logical conclusions have been arrived at, which in brief, are thus stated by Gibbs: "It was found that all types of locomotives (referring to electric—R.V.M.) were practically steady at speeds under 40 miles per hour, but that above this speed, marked differences appeared, that the steadiest riding machines were those with high centre of gravity and with long and unsymmetrical wheel base. In other words, that the nearer steam locomotive design is approached in wheel arrangement, distribution of weight, height of centre of gravity and ratio of spring-borne to under-spring weight, the less the side pressures registered on the rail head."[1] Modern locomotive design is such that the cost for maintenance of way and structures is much less than with earlier designs and further improvement is hoped for.

Locomotive Repairs and Maintenance

It has been generally recognized that repair and maintenance cost of electric locomotives should be low; the main reasons being:— (1) Motive power equipment is of simple construction and moving parts are few, hence repairs are few; (2) Weight of locomotives is small per horse power; (3) On account of simplicity of construction, efficient inspection is facilitated; (4) Reliability of electric locomo-

1 "Report No. 2. On the Question of Electric Traction." By George Gibbs. Bulletin of International Railway Congress, Jan., 1910. Page 251.

tives is high, so that few spare units are necessary; (5) Electric locomotives are capable of almost continuous operation, for long intervals hence the minimum number of locomotives to handle the traffic are required.

Economics of Electrification

In discussing the general economic aspect of electrification as applied to trunk line railroads, it must be borne in mind that railroads are built and operated for the express purpose of making profits, or a return on investment over and above the cost of operation and fixed charges. (Possible exceptions to this rule are government roads and private industrial railways). Consequently, arguments favoring electrification must be presented to the practical railroad man in the form of "dollars and cents"; and this is sometimes a most difficult thing to do. However, any specific electrification problem is generally sufficiently susceptible of analysis as to allow the engineer to state within reasonable limits what return should be realized from the adoption of electric traction.

It should be noted that in some instances (notably the New York Central and Hudson River Railroad tunnels at New York City) the law has intervened and made compulsory the adoption of electric traction for certain limited service. In such cases it becomes merely a question of, "Which is the best system for present service and future requirements?" and not, "Is electric operation, from a financial standpoint, preferable to steam operation, for a given division or divisions?"

Electrification, like any other extensive engineering work, involves the investment of a large amount of money, against which there are always "fixed charges," consisting of interest, sinking fund, etc., and such investment is not justifiable, unless an increase in net receipts can be secured which is more than sufficient to pay interest on the extra capital involved.

There are two ways in which an increase of net receipts can be brought about, namely, by decreasing the working expenses for the same service, by so modifying the service as to bring in a greater revenue, or by a combination of these.

There follows a brief discussion of the more important advantages claimed for electrification on heavy railroads. It will be noted that some of these advantages, which might be termed physical advantages (such for example, as increased safety) are extremely hard to capitalize, and their consideration might be more a matter of policy and broad judgment than a simple case of financial advantage.

Capacity

Capacity is certainly among the most important advantages which may be secured by electrification. It has been said that the keynote of electrification is capacity. By approaching the problem from this standpoint only, can full benefits be obtained.

In truck line service, capacity is desirable in the motive power, in the track and in the terminals.

With electric traction it is a simple matter to secure capacity of motive power, either in single locomotive units or in motor cars. In the case of electric locomotives, great power capacity can be concentrated in a single locomotive, also the multiple unit system of operation allows of two or more locomotives being coupled together and operated in exactly the same manner as a single locomotive; the advantages of having the train operated by a single crew in the front locomotive are obvious. In the case of motor car trains, it is possible, by equipping all axles to get a very great equivalent drawbar pull, and the high rates of acceleration used in multiple unit motor car train operation are thus made practicable.

Capacity of locomotives is a very important point, especially in heavy freight service in general and in heavy grade work in particular; the modern tendency being towards the use of the heaviest trains practicable (heavy trunk lines run freight trains of 2000 tons to 3500 tons and as high as 4500 tons).

As stated before, great capacity of steam motive power can only be obtained by either double heading steam locomotives or by using Mallet articulated compound engines, so ably described by Mr. F. H. Moody in the March issue of this journal. The former method means doubling of locomotive crew and unsatisfactory operation of locomotives—this being accomplished by two independent engine crews. The latter method has found extensive employment for heavy grade service but its application to long haul service is not at all extensive with the present state of the art.

Another phase of locomotive capacity besides horse power and one that can be greatly increased through electrification, is that represented by the "number of miles per locomotive per month." The electric locomotive is capable of almost continuous service at full rated capacity, whereas the steam locomotive spends a very considerable part of its time in repair shop and round house. In this connection, an analysis, made by the committee of the American Railway Master Mechanics' Association on time service of steam locomotives, on a large trunk line covering a three months' period, is given as showing the low mileage accomplished by the average steam locomotive. The test brought out the following facts:—

1. The steam locomotive is actually hauling trains only 28% of the time—making 3000 miles per month, or 100 miles per day.

2. The mechanical department is responsible for 22% of the time.

3. During 50% of the time, the locomotive is under steam, with crew and ready to go—this is the time spent on side-tracks, at terminal yards and awaiting orders.[1]

The electric locomotive can make greater mileage than its steam competitor for several reasons, namely:—

1. Greater average speed is obtained.

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1 "The Electrification of Trunk Lines." By Mr. L. R. Pomeroy. Proceedings Institution of Mechanical Engineers July, 1010. Page 1202.

2. Less time in repair shops.
3. Roundhouse operations almost eliminated.
4. On account of greater reliability, superior conditions of operation are possible, thus the idle time spent on sidings, in yards, and awaiting orders is cut down, though by no means eliminated.

Capacity of tracks and terminals is also a most important advantage secured by electrification. In cases where, with steam operation, the tracks are congested and it would be necessary to add more trackage, it is often possible by electrification to so far increase the capacity of the existing trackage as to make unnecessary such expensive improvements as grade revision and changes in trackage and right of way. In special cases—for example, large cities, tunnels, mountain grades, etc., it is possible that the increase of trackage capacity incident to electrification, by making double tracking, or right of way changes unnecessary, would be the controlling factor in effecting a decision as to the advisability of electrifying.

The increase of passenger terminal capacity by electrification is a matter of common knowledge. It has been demonstrated in actual service that the capacity can be about doubled.

Increase of capacity of freight terminal yards can also be effected by electrification, though in this case it is not so marked as in the case of passenger terminals.

Flexibility and Simplicity

Multiple unit arrangement of locomotives and of motor cars provides a most flexible and economical system of operation. Electric locomotives and motor car trains can be operated equally well in either direction, and consequently switching operations are greatly decreased and turntables are eliminated. The mechanism of an electric locomotive is manifestly much simpler than that of a steam locomotive and advantages of simplicity are obvious.

It may be objected that the multiple unit control systems are far from the acme of simplicity. This is true of both the general systems in use. These systems being respectively: The Sprague-General Electric, which is a straight electric control system, and the Westinghouse Electro-pneumatic system, which employs an electric control circuit to govern the valves which admit compressed air to the devices operating the motor circuit switches. In spite of their apparent complications, both systems have stood the test of severe service with remarkably good results. In actual operation, both systems have been found extremely reliable.

It has been demonstrated by several years of operation that electric trains are safer and more reliable than steam trains. In view of statements sometimes made regarding reliability of electric trains, the following figure concerning recent operation on the one-time much criticized New York, New Haven and Hartford Railroad. is conclusive. A train having a delay rate equal to the average delay rate of all trains operating on the electrified divisions would go from New York City to San Francisco and back eleven times with only

three minutes delay. Such a figure is beyond the dreams of any steam operating engineer.

The familiar "weather ratings" applied to steam locomotives disappear from the horizon of electric traction; wind and snow and cold are more pleasant than summer zephyrs to the electric locomotive. To keep cool is its ambition.

Traffic Increase

Beyond doubt, passenger traffic can be largely increased by electrifying, due to inherent advantages of electric trains and also to the fact that superior operation becomes possible and practicable with electric motive power, especially in the matter of speed and frequency of trains. The greatest increase of passenger traffic is in connection with local runs which are made by light motor car trains. Since, as before pointed out, these trains are able to accelerate to full speed in a very short time and are also able to make very quick stops, a great increase in schedule speed over that obtainable with steam trains, results in a service which requires frequent stops. Since heavy locomotives are eliminated and train make-up is most flexible, it is possible to run this class of train over the system at short intervals. Increase of schedule speed and increase of frequency of trains have the effect of greatly augmenting the traffic from that class of patrons known as "commuters," and since most electrifications are and will be in future in densely populated parts of the country this class of traffic is deserving of large consideration.

It is reasonable to expect some increase of freight traffic due to the general recognition of superior service by electric traction—particularly as regards safety and reliability. In some cases a great increase of freight traffic can be effected through the electrification of terminals, and branch lines, which are the feeders for the main lines.

The traffic fostering effects of a high class local electric service, both freight and passenger, have been demonstrated in no uncertain way by the great electric interurban systems which in many cases directly parallel great trunk lines and are a source of great financial loss to those roads as well as being a monument to their lost opportunities. By electrifying certain divisions, much of this traffic can be regained and further traffic developed by the trunk lines.

Coal and Water Saving

Steam locomotives at their best, are necessarily much less efficient than large central power stations, and the contention that electrification would result in great savings in coal has been borne out in practice. Money is saved by using less coal and cheaper coal than is permissible on locomotives. Considering average heavy trunk line conditions, it has been found that to produce the same ton-miles by electric power as by steam power in passenger service requires very nearly 50% less weight of coal. For switching work the electric locomotive requires only 33% as much coal as the steam locomotive. Stillwell and Putnam estimated that if all the railroads in the United States were to electrify, the total cost (not including

fixed charges) of energy for traction, for the operation of auxiliaries, and for the supply of light and heat to passenger trains, would closely approximate 50.5% of the cost of fuel for steam locomotive service. Several years of extensive operation seems to indicate that this figure is approximately correct; being perhaps a trifle too low on account of the tendency to increase speeds under electric operation.

The cost of water supply at innumerable points along the lines is entirely saved. Also delays due to the taking of water are obviated. With electric operation water is required at the central stations only, and its cost is very small, and in any case, would be included in the cost of power.

In connection with the coal and water saving, it should be noted that with electric traction, the tender is eliminated and thereby a source of expense and non-revenue train weight.

Maintenance of Way and Structures

Included under this item is a large number of factors which are subject to great variation. Due to the absence of smoke and cinders the maintenance cost of structures along the road is greatly decreased. As regards the cost of maintenance of way, it is difficult to make accurate statements, since this item depends to such a large extent on character of service and character of equipment. It was formerly thought that great economies would be effected in this department, but such has not been the case up to the present. Locomotive and motor truck design is progressing very rapidly, but at the present time it may be said that for heavy trunk lines with a mixed service, the maintenance of way cost will be as large or larger for electric as for steam operation. When the maintenance cost of the contact system is added, it may safely be said that the cost of maintenance of way and structures will be considerably greater for electric than for steam operation.

Maintenance of Equipment

The cost of maintaining equipment is one of the large expense items of steam railroads. The three largest sub-items are the repairs and renewals to locomotives, freight cars, and passenger cars respectively.

The maintenance cost of electric locomotives is much less than that of steam locomotives, due largely to the fact that electric locomotives are very simple in comparison to steam locomotives and are not so severely handicapped by reason of their operating characteristics. As the capacity of the locomotive increases, the ratio in favor of the electric locomotive becomes greater and greater. on account of the extremely heavy maintenance cost of large steam locomotives. Where Mallets are used it has been found that the cost of maintenance is about 23c. per locomotive mile, and that they are out of service about 25% of the time. The maintenance cost of Consolidation type locomotives is well known to be from 7c. to 10c. per locomotive mile. The best available data points to a mainten-

ance cost of 3c. to 8c. per locomotive mile for heavy electric locomotives. Just here it is pertinent to remark that repair costs of locomotives, when electric and steam operation are compared at least, would be more properly stated in terms of cents per ton-mile than in cents per locomotive mile; this is evident when it is considered that ton-miles, and not locomotive-miles, are the revenue producers. Also to make a complete comparison between steam and electric operation, total costs should be given and not unit costs—the reason of course, being that one steam locomotive is not the equivalent of one electric locomotive in terms of ton-miles per month. When the matter is considered in this light the ratio in favor of electric traction appears in its correct form. After long study of mixed freight and passenger service under heavy trunk line conditions, Murray places the ratio of steam locomotive repairs to electric locomotive repairs as three to one.[1] In view of previous statements and references this figure will appear reasonable.

In electric service where locomotives are used, passenger cars have a lower maintenance cost than under steam operation, chiefly on account of the absence of smoke and cinders, also on account of somewhat smoother operation.

Where motor cars are used it is difficult to find a "common denominator" for rendering of steam and electric comparisons. This is due to the fact that motor cars combine the functions of passenger cars and locomotives on steam lines, but in general, they give a considerably different service. Operating cost of motor cars is generally given in cents per car mile and maintenance of motor car is a sub-item of this. For any definite electrification problem where it is proposed to change from steam service to a multiple unit motor car train service, data is obtainable such that cost of operation can be determined; but it seems impracticable to compare maintenance of equipment per car mile for multiple unit service to any analogous item for steam service. In other words, the whole service must be considered, both the costs per car-mile and the possible revenue per car-mile and the total car-miles which will be required. Abundant evidence is at hand to show that the total operating cost (not including fixed charges) per car-mile in favorable multiple unit service is much less for electric than for steam operation.

With respect to freight cars, the maintenance cost might be a little less with electric operation but any difference would probably be so small as to be negligible.

With electric operation, the wages of train crews are decreased on account of less idle movements, less stand-by time, less men per ton-mile in locomotive work. Wages in other departments will in general be decreased but these items might be more readily included as integral parts of the operating expense of the departments affected.

By-products may seem an insignificant term, but it can truthfully be said that some by-products of electrification on large trunk

1 Discussion on "Electric Motor vs. Steam Locomotives." By William S. Murray. Transactions A.I.E.E. Vol. XXVI. Part I. Page 150.

lines are of considerable financial importance. Among the more important by-products, the following are obvious:--lighting and power bills for stations, sheds, shops, yards, elevators, etc., are decreased; real estate values all along the route are increased, due to the abolition of the smoke and noise nuisance; it is possible to construct double-deck freight terminals with extensive warehouses over the tracks and efficient methods of freight handling are made possible; in case of passenger terminals, land is economized due to increased capacity of a given number of tracks; in large cities, double decking of tracks is possible, also large office buildings may be erected over the terminal tracks.

In conclusion, it may be said that steam railroading to-day is largely steam-locomotive practice and that the full advantages of electrification are only reached when the whole system of operation is changed to conform to the new operating characteristics. Commenting on this aspect of electrification, McCrea of the Long Island Railroad, does not hesitate to say after six years of electrical operation, that if the road were forced to revert to steam operation, "It would be necessary to abandon much of the service which would not be possible under the restrictions of steam operation."[1]

What has been accomplished during the last 16 years, is no criterion of what could have been accomplished had the art of electrical engineering, and especially electric railway engineering been as fully developed as at present. As to the future of electrification, conditions point to the progressive adoption of electric traction first in the more favorable situations, such as tunnels, heavy grades, around dense centres of population, and then a gradual extension farther and farther out on the trunk lines as the art develops and as economy and policy dictate.

E. H. Niebel, '09, has entered the employ of the Northern Electrical Manufacturing Co. in Montreal.

J. B. Goodwin, '92, is Superintendent of the Mount Hood Railway and Power Co., at Portland, Ore.

H. P. Elliott, '96, Industrial Engineer, has changed his address in Toronto, from Manning Chambers to 36 Toronto St.

W. Mines, '93, is Chief Engineer for Hoover & Mason, Chicago

W. V. Taylor, '93, is Assistant Engineer for the Board of Highway Commissioners of Quebec.

C. R. Redfern, '09, until recently assistant superintendent of construction for P. Lyall & Sons, on the Terminal Freight Station of the C. P. R. in Toronto, has been appointed Assistant Engineer, Roadway Dept. of the City of Toronto.

1 "Notes on the Electrification of the Long Island Railroad." By J. A. McCrea. Proceedings of New York Railroad Club. March, 1911. Page 2354

SPECIAL TRACKWORK FOR CITY ELECTRIC RAILWAYS

W. E. Turner, B.A. Sc.

In the construction of electric railways in cities, and especially in paved streets, the special track layouts constitute one of the most important items to be decided on, ordered, constructed and maintained by the engineering department. The high first cost, high maintenance, and quick depreciation of even the best layouts, make them an item of great importance to the company.

As a general rule the street railway company does not manufacture its own special work and it is not the intention of this article to deal with the manufacture of specials, but rather to present a few of the most important considerations for the engineer of the railway

Fig. 1

and at the same time to explain terms and conditions which may not be familiar to those who have not encountered much special work.

A special layout is a combination of switches, mates, frogs, crossings, and curves, arranged to make connections between different tracks. In its simplest form it is a plain ninety degree crossing of two tracks, and in its more complex phases it becomes a very intricate network of steel.

Fig. 1 shows a sample layout of average complication for a business district intersection. This particular instance is what is known as "the Brigham Young Layout," surrounding the famous statue of Brigham Young at the corner of South Temple and Main Streets in Salt Lake City. In the background may be seen the Mormon temple and tabernacle, the latter having the curved roof. This layout is on the tracks of the Utah Light and Railway Company, and the other illustrations and descriptions are drawn largely from this company's standard practice. It may be interesting to note that the Brigham Young layout lost about $13,000, complete, in place, and repaved.

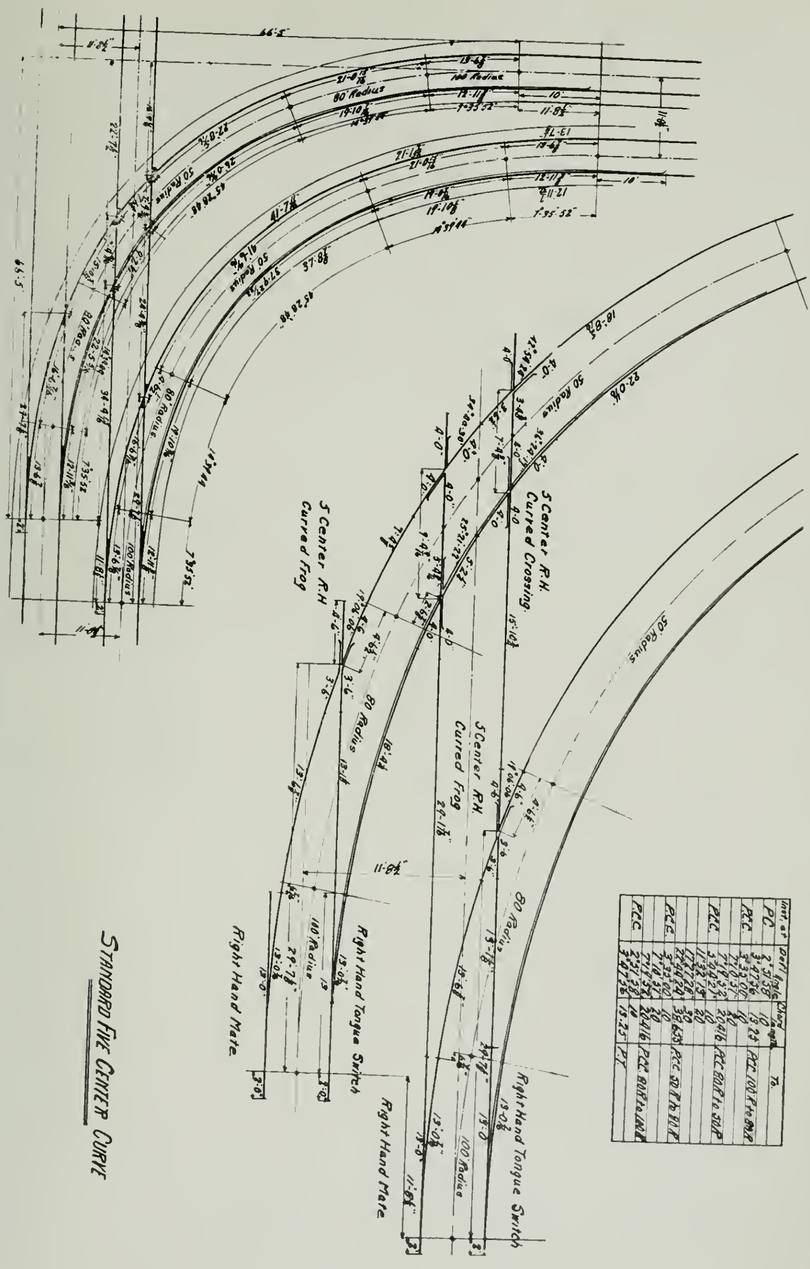
In Fig. 2, showing a five-centre curve, may be found the names of the most commonly used pieces in track layouts. It will be noticed that in all cases tongue switches and mates are referred to instead of split switches, which are used entirely on steam roads, but very seldom on city electric lines. There are right and left hand switches, those shown on Fig. 2, being known as right hand because the curve turns to the right when entering it from the switch. There are also right and left hand curved frogs and crossings.

A cross-over is a connection between two parallel tracks as shown in Fig. 3. The switches and mates are the same as those shown in Fig. 2, but in this case we have straight frogs and it is not necessary to carry them in "rights" and "lefts." Right hand cross-overs are always preferable where the traffic takes the right side of the street on account of avoiding a "facing switch," that is, one in which the point of the tongue faces the approaching car. Cars must stop or run very slowly when passing a facing switch. A turnout is similar to a cross-over except that the second track ends at the turnout instead of going right through. Sometimes spring switches are convenient at turnouts (see Fig. 7). For instance, if all the traffic going south takes the turnout, and all going north takes the through track, the switch may have a spring holding the tongue in position for the turnout. It is evident that cars going north will enter the switch from the rear end and spring it out of the way as they pass.

Besides the above commonly used "specials," there is an infinite number of odd pieces, such as the frog of one curve combined with the mate of another, double frogs, etc., but such cases can only be described by individual drawings.

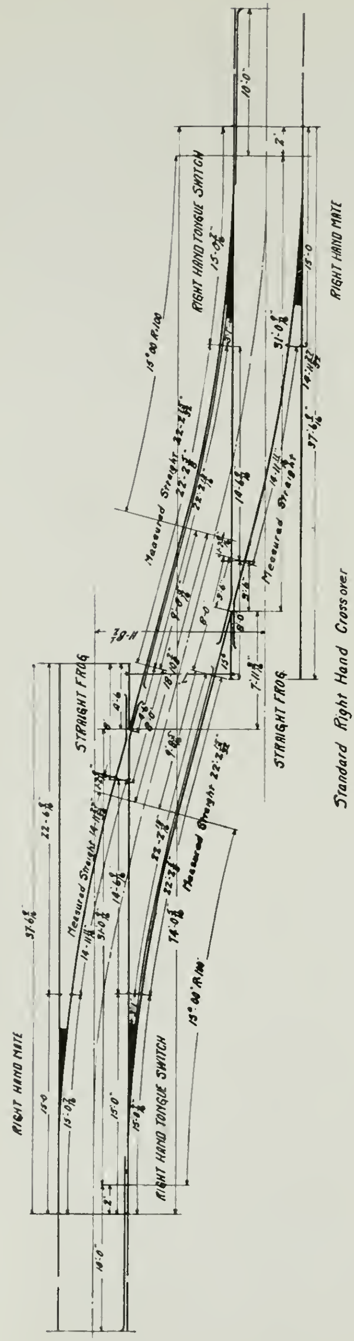
A type of special work frequently used is what is known as the bolted or built-up construction, in which the specials are built up of pieces of rail, planed off to fit together, bent for wings and curves, and bolted through steel bars and cast steel fillers. Practically all steam road specials are made in this way, and being the least expensive form of construction, the built-up specials are adaptable to electric roads in unpaved streets where traffic is light. They are used extensively for steam and electric crossings.

A more rigid form of construction is the cast iron body which, in the molten state unites so closely with the rail components as to form practically a solid mass. The cast body has usually the hardened renewable centre as shown in Fig. 4. Notice this type of



Inst. at	Defl. Angle	Chord length	To.
PC	2°51'58"	10	
P.C.C.	3°47'36"	13.25	P.C.C. 100' R to 80' R
	3°33'00"	10	
	7°10'37"	20	
P.C.C.	7°19'52"	20.416	P.C.C. 80' R to 50' R
	3°44'27"	10	
	11°32'19"	20	
	17°47'26"	30	
P.C.C.	22°44'24"	38.635	P.C.C. 50' R to 80' R
	3°33'00"	10	
	7°10'37"	20	
	7°19'52"	20.416	P.C.C. 80' R to 100' R
P.C.C.	2°51'58"	10	
	3°47'36"	13.25	P.T.

Fig. 2



Standard Right Hand Cross over

Fig. 3

construction on the Brigham Young layout, Fig. 1. The centre plate is hardened by patented and more or less secret processes, a very satisfactory combination being manganese steel, which will wear probably four times as long as ordinary rail steel.

The most substantial, and incidentally the most expensive, specials are simply solid castings with no rolled sections, but with the ends cast in the form of rolled sections to join abutting tracks. Such castings are used for very complicated pieces, and for points of heavy traffic, such as important steam road crossings in pavement, in which case the whole crossing is sometimes cast solid of hardened steel. See Fig. 5. This form is quite expensive to use.

In examining Fig. 5, it might be well to notice the wide ball on the steam road side. This takes the place of two rails, known in built-up construction as the running rail and the easer rail, and the narrow strip on the other side of the groove takes the place of the guard rail. On the electric line the easer rail is omitted.

Hardened steel rails may be obtained for use on curves where the wear is very excessive Titanium alloy steel has been recently introduced for this purpose.

In deciding what layouts are necessary for any particular system, the first consideration is, of course, the traffic, that is, the regular car routes and special car routes for such purposes as getting in and out from barns, parking cars for resorts or circuses, fair day routes, etc. The next matter of importance is

the geographical situation—width of streets, location of curbs, distance between track centres, and possible obstructions such as poles.

At the same time it is well to investigate whether cars can pass each other on curves. This can most conveniently be done by drawing up to scale a double track curve, such as shown in Fig. 2, and drawing on a separate piece of tracing linen, to the same scale, the longest car likely to be used, with the centres of both pivot plates marked. The drawing of the car is cut out and placed on the curve. By following the centre line of the track with the two pivot plates, a clearance curve may be traced where the end of the car overhangs most.

Besides these fixed conditions to be encountered, the engineer must himself fix a condition—to make every possible piece of special

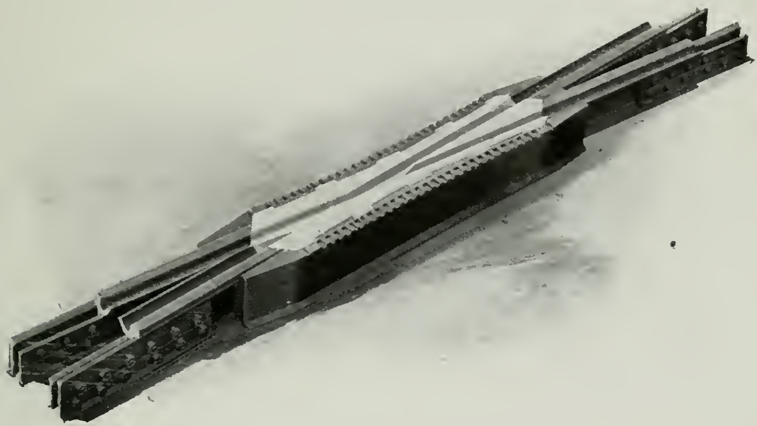


Fig. 4

work comform with certain standards. For instance, there is no reason why practically every switch and mate on the system should not be made for a 100-foot radius curve. The greatest advantage in conforming to standard pieces, is, of course, interchange ability and keeping down the stock which must be on hand for repairs, and other great advantages are the reduction in office work on ordering, keeping of records, keeping stock, in the field in laying out work, and in the shop and track departments by having pieces with which the men are familiar. Track should be standarized by using only one or two standard rail sections throughout the system, such as 65-pound A. S. C. E. rails, but where a variety of sections is used it is generally better to employ compromise joints to the special work than to order specials in odd sections.

If all double tracks are maintained at a fixed distance between centres, it will be a great step towards holding to standard special work. That will at least provide that all crossovers and turnouts

may be standardized and will insure the same advantage to curves to a very large extent.

In the design of curves the first consideration is to fit the ground and clear obstructions, the second to use standard pieces in every place possible, and the third to get the greatest available radius of curvature. As the most of the street intersections will probably be of similar design, a standard curve such as shown on Fig. 2 may be employed for all such places. In Salt Lake City, there are two standard curves in use, viz., the five-centre curve, which is shown in Fig. 2, for narrow streets, and a three-centre curve for the broader streets. The least radius in the three-centre curve is 66 feet 7 inches, and in the five centre curve, 50 feet.

A compound curve, such as is shown in Fig. 2, facilitates sharp curves on corners, permits the standard 100-foot switch and mate, and swings the car gradually from large to smaller radii. Its use is to be preferred to a plain curve. It is easily laid out in the field by

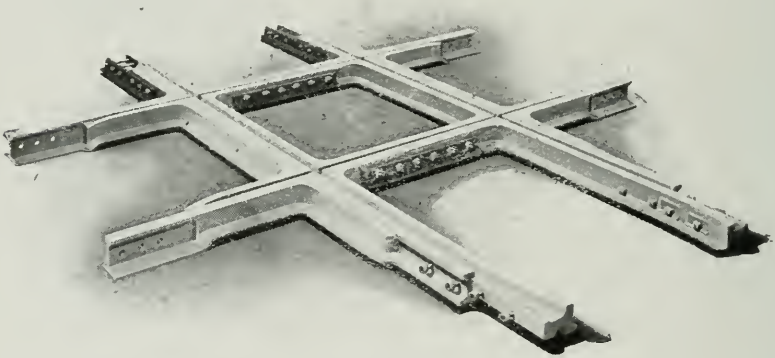


Fig. 5

reference to the table in the corner. Some of the large steel companies recommend spirals at the entrance to curves. Instead of running over a 100-foot radius and an 80-foot radius to get to the central 50-foot curve, they would start with a 100-foot radius and spiral around by an infinite series of decreasing radii to reach the 50-foot curve.

In connection with the least radius of curvature practicable for general use it is a matter impossible of accurate calculation and one upon which authorities differ. Curves of as small as 35-foot radius, and possibly less, are in use, but it is conservative practice to establish a limit at 50 feet. On a 50-foot curve the rail wear is very excessive, wheel depreciation is high, and the load on line and motors is severe.

Referring again to the necessity of standardizing all pieces, a list is given of the specials usually carried in the Utah Light and Railway Company's stock, as an illustration of the number of pieces

necessary even when all work is standardized. The 80-pound specials are high tee rail for use in the commercial district, and the 65-pound A. S. C. E. for use elsewhere. It will be noticed that frogs are not referred to by number according to steam road practice, as that system is not applicable to right and left hand curved frogs.

LIST OF SPECIALS CARRIED IN STOCK—U.L. & RY. CO

	Frogs	Curved Crossings	
80℔ R.H. switches	80℔ RH. 5C	80℔ R.H. 5C	80℔ straight 15° frogs
80℔ L.H. switches	80℔ L.H. 5C	80℔ L.H. 5C	80℔ square crossings
80℔ R.H. mates	80℔ R.H. 3C	80℔ R.H. 3C	
80℔ R.H. mates	80℔ L.H. 3C	80℔ L.H. 3C	
65℔ R.H. switches	65℔ R.H. 5C	65℔ R.H. 5C	65℔ straight frogs
65℔ L.H. switches	65℔ L.H. 5C	65℔ L.H. 5C	65℔ square crossings
65℔ R.H. mates	65℔ R.H. 3C	65℔ R.H. 3C	
65℔ L.H. mates	65℔ L.H. 3C	65℔ L H. 3C	

Note.—R.H. and L.H. denote right and left hand, respectively.

Besides this list there are some odd pieces left from previous administrations. The above are all of the manganese centre, cast

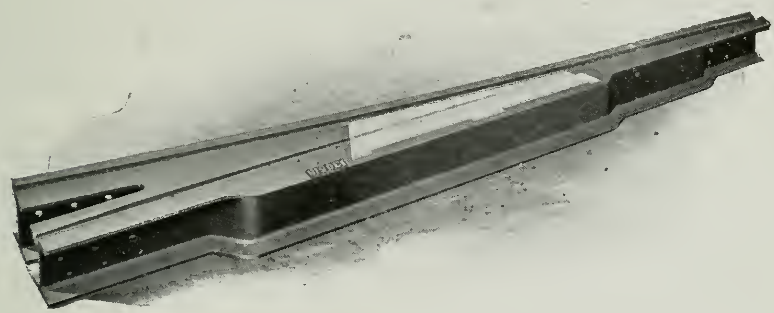


Fig. 6

body type. Steam road crossings are all special and ordered as required and are mostly of the bolted construction bought on a tonnage basis.

As the listed specials range in value from $90 to $400, they represent a considerable investment. The stock is piled in the material yard along tracks. The pieces are marked 5CL, 3CR, etc., and they are handled with a light derrick car.

Drawings should be made of all standard layouts showing distinctly the track alignment, gauges, length of wings required and in ordering the specials the above drawings may be sent to bidders without any detailed drawings of the construction, and without any rail lengths, frog angles, or other details which may be readily worked out from the data given. The steel companies always re-calculate these items and use one of their standard forms of construction on the

specials. An exception is in the bolted or built-up construction for which it is well to have a standard drawing, showing type of construction preferred, in detail but leaving out angles, radii, wings, rail sections, etc., which must be filled in for each individual case on a separate skeleton drawing.

An order for specials should cover the points to be found in the following sample order.

Sample Order

Three crossings, right hand, standard 5-centre curve, hardened steel renewable centre construction, C. I. body, for use with 7in. 80-pound rail, Lorain section No. 335 with 1in. by 5½in. bar guard plate as

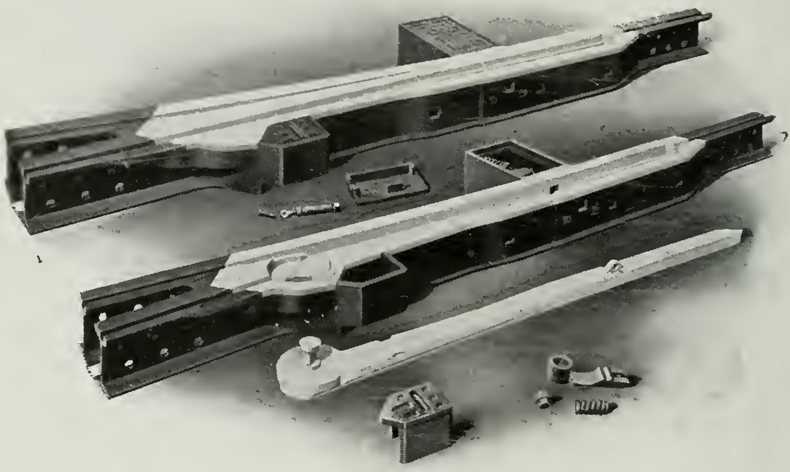


Fig. 7

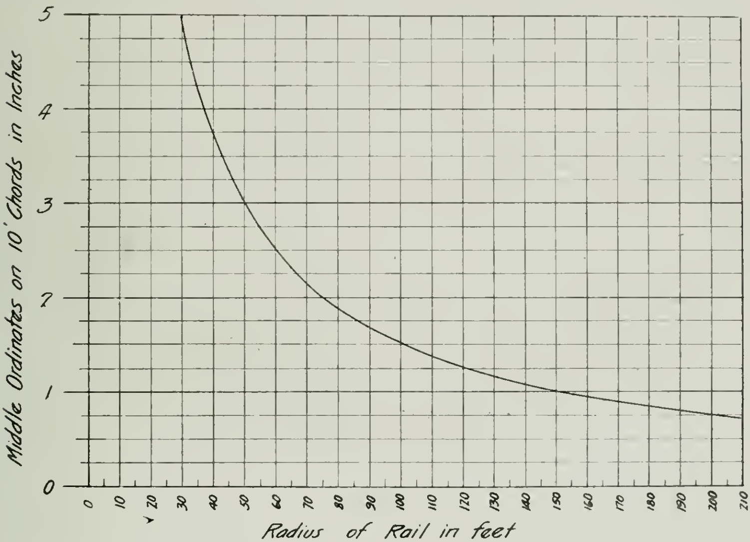
shown on drawing, No. X. Drilling for track bolt, 3-in. 6in. 1 1-8in holes; for bonds 31-32in. holes 6in. from ends, all 3¼in. above base of rail. See drawing No. Y for drilling. General layout on drawing No. Z (see Fig. 2). (It is sometimes advisable to refer to a catalogue number for type of construction.) All the drawings mentioned may be on the same or different sheets.

Whole layouts may be ordered complete from the steel companies and for complicated layouts it is a good idea to have them made up completely in the same shop, and every piece marked according to blue print. For instance, the Brigham Young layout, Fig. 1 was ordered complete and is all made of guard rail section.

It is customary to make up all simple layouts which require only the standard stock specials, in the railway company's shop For this purpose, besides having access to a blacksmith shop, there

should be a rail bender, a fairly heavy drill press, a metal saw and saw sharpener. The track shop should be convenient to a vacant space large enough to fit together one or more layouts before taking them to the work.

Layouts are staked out with a transit at the shops and in the field (see transit notes on Fig. 2), For all curves which are not standard the following information is supplied by the engineering department for use of field and shop men; all data necessary for the exact location of track centres such as the P. C., radius and central angle of each curve, the distance between track centres and lengths of tangents. The following details more particularly for the shop men; size of rail, lengths of specials, location of switches, mates and frogs from point of curvature, lengths of each piece of rail measured straight



MIDDLE ORDINATE CURVE FOR RAIL BENDING

Fig. 8

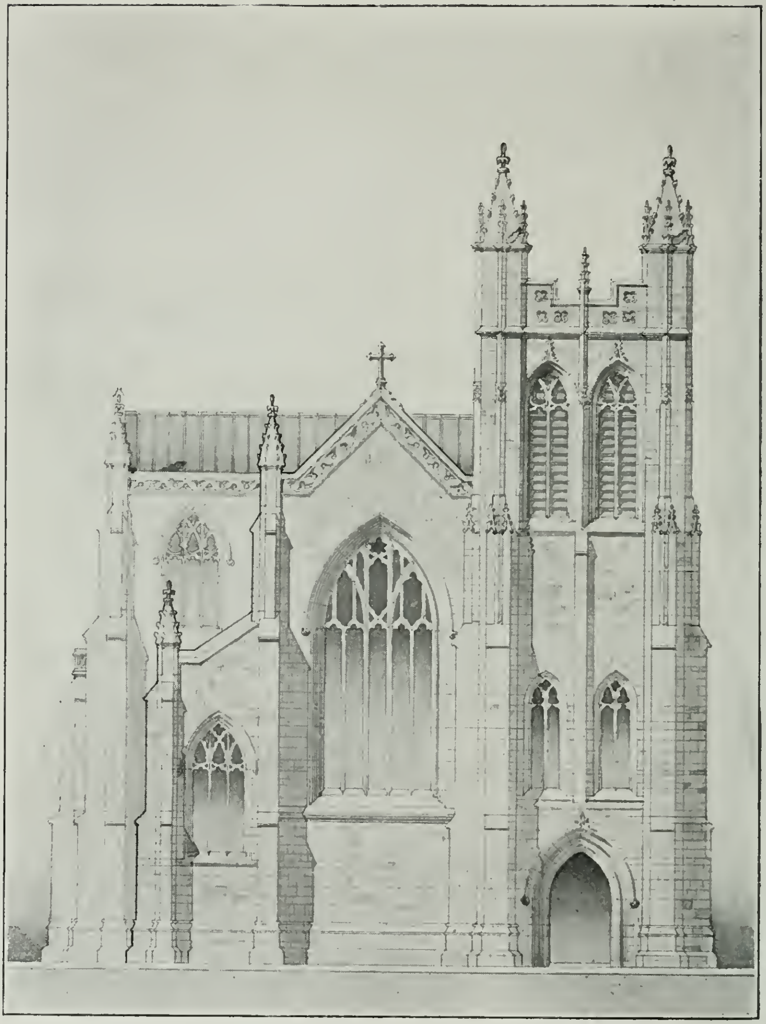
before bending and the middle ordinate of each curved rail on, for example, a 10-foot chord.

Two points might be noted in connection with this, first, that the description of curves by degree of curvature is not convenient when the radius is small, and second, that drawings or measurements, showing the location of the points of frogs or crossings, refer to the intersection of the two gauge lines and need not necessarily coincide with any actual point.

Fig. 5 is a curve showing middle ordinates on a 10-foot chord for different radii of bent rails. For very sharp curves the middle ordinate is different for the outer and inner rail. This curve is derived from the very simple formula—

Middle ordinate $= R - \sqrt{(R + \frac{1}{2}C)(R - \frac{1}{2}C)}$ where R = radius in feet of the bent rail, and C = the chord length in feet.

In the case first considered, the length of chord is 10 feet.



DESIGN FOR CHURCH

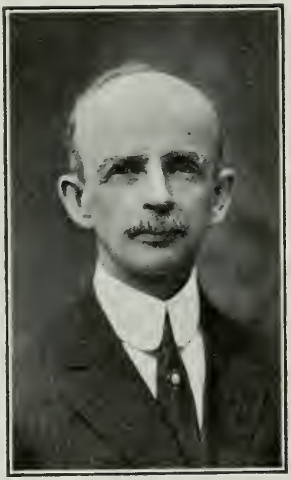
Elevational drawing by L. C. M. Baldwin. The plan is illustrated on page 140

BIOGRAPHY

The location of Mr. D. Jeffrey of the graduating class of 1882, has not been clear to us for several years. Mr. Jeffrey, when we last heard from him, was engaged in general contracting work at Windsor, Missouri, having previously carried on the same line of activity in Winnipeg, Manitoba. Mr. J. McAree, also a member of the class, was, prior to his death, eight years ago, engaged in Dominion Land Survey work in what was then known as the North West Territories. Concerning the third member of the class, Mr. J. H. Kennedy we had a good deal to write in the July issue.

D. BURNS, '83

Of the class of 1883, Mr. David Burns, whose photograph accompanies this biography, after having followed actively the profession of the engineer for over twenty years after graduation, is one of the few who reverted to academic work, his services having been acquired by the Carnegie Institute of Technology in Pittsburg.



D. Burns, '83

For a year after leaving the School, Mr. Burns was engaged on location and construction work on the Burlington and Missouri Railroad in Nebraska, and in 1885 became connected with the staff of the city of Toronto waterworks. In 1886 and for the three following years, he was a member of the teaching staff of the School of Practical Science, holding a Fellowship in Civil Engineering. He then became engaged in general survey work about the city. In 1891 Mr. Burns accepted a position in the chief engineer's office of the Pennsylvania Railroad in connection with lines west of Pittsburg. He held this position for two years, resigning to enter the office of the city engineer of Allegheny, Pa., to prepare plans for the elimination of grade crossings in that city.

Beginning in 1895, Mr. Burns spent seven years on bridge construction, first in the Keystone Bridge Works and later with the American Bridge Co. He returned to railway work in '02, and immediately put his knowledge of bridge engineering into practice on the construction of the West Side Belt Railroad, having charge of all bridges on its right of way.

When he again accepted the responsibilities of an instructor it was at the close of 1904, and the institution mentioned above, then known as the Carnegie Technical Schools, was the favored body. He carried into the organization a wealth of practical knowledge, derived from observation and application in many bracnhes

of engineering, and his ability was readily recognized, in his appointment as representative in April, 05, of the Carnegie Institute of Technology, in the erection of its buildings. He has since occupied a chair among the members of the Faculty.

Mr. Burns was granted a certificate, in April, 1890, as Land Surveyor for the Province of Ontario. He is an Associate Member of the Canadian Society of Civil Engineers.

WHAT OUR GRADUATES ARE DOING

W. O. Boswell, '11, has accepted a position with Reid, Limited of Newark, N. J., on electric furnace work.

Mackenzie Williams, '09, is connected with the firm of A. E. Ames & Co., Toronto.

W. S. Steele, '11, is on the engineering staff of the Brooklyn Rapid Transit Co. of Brooklyn, N. Y.

E. A. Greene, '11, is in the employ of the Montreal Light, Heat & Power Co.

M. Kirkwood, '11, is engaged with the Crocker-Wheeler Co., Ampere, N. J., in their D. C. engineering office.

J. H. C. Waite, '11, is at Giroux Lake, in the employ of the Drummond Mines.

W. H. Wilson, '10, and W. D. Walcott, '11, are in the engineering office of the National Bridge Co., Montreal.

W. A. O'Flynn, '11, is assistant engineer in the metallurgical laboratory of the Copper Queen Smelter, at Douglas, Arizona.

J. M. Duncan, '10, is marine engine draftsman for the Collingwood Shipbuilding Co.

Angus Smith, '94, until recently City Engineer of Victoria, is now engineer for the municipality of North Vancouver.

J. A. Morphy, '11, is in Prince Albert, Sask., where he has a contract to lay a number of sewers.

W. R. Keys, '08, is engineer for the T.C.R., on a branch line being built to Elk Lake.

A. P. Linton, '06, has been appointed assistant chief engineer for Saskatchewan, while E. W. Murray, '07, is district surveyor for the province.

J. H. Brace, '08, has for the past year been engaged in telephone engineering with the Bell Telephone Co., at Montreal. Mr. Brace has also had three years' experience in the same line of work with the New York Telephone Co.

J. V. Culbert, B.A.Sc., a member of the class in mining of '07, has been appointed mill superintendent of the recently-completed mill of the Hollinger Gold Mines, at Porcupine. This mill is the largest in Porcupine and treats the gold ore by plate amalgamation, table concentration and cyanidation of tails by the slimes process.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published every month in the year by the University of Toronto Engineering Society

SUBSCRIPTION RATES

Per year, in advance	$2.00
Single copies	20

Advertising rates on application

Address all communications:

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

EDITORIAL

A NOTEWORTHY COMPARISON

Now while the Dean is taking a few days' recreation around the northern lakes is our best chance. The oft-reiterated appreciation of his co-operation and assistance in all things that indicate strength and unity among the graduates and undergraduates of the Faculty of Applied Science and Engineering, barely escapes another voicing in every issue of this Journal. Since the days when Engineering Society itself merely inhabited the minds of the few, it has not been wanting in his support and advice. Every healthy project attendant upon school life owes in a like manner its constitution and staying powers to the steadying influence of the Dean. The Engineering Society is but an example of the force behind the institution.

Anent his great work the *Canadian Engineer* in a recent issue has this to say editorially:—"Dean Galbraith was appointed Pro-

fessor of Engineering in 1878, and for the first few years of the School's existence, he did all the engineering teaching. It is a noteworthy fact that the main features of the course, as then laid down, still control the policy of the Faculty. As Professor of Engineering, Dean Galbraith held that the practice of engineering should be learned in the field, and that the course in the School should consist of a ground work of pure mathematics, and a broad training in principles, followed by illustrations of the applications of the principles. He believes, and has consistently followed his belief in directing the trend of development, that everything should be made subservient to the idea of the application of principles. His oft repeated statement:—'We do not make engineers; we prepare them to become engineers' is worthy of record."

The editorial proceeds to comment upon a comparison of the salaries allotted to various members of the University staff, and mentions that of our Dean as being lower than a number of them. It states that "aside from his personal record this position of head of one of the most important faculties in the University demands recognition at least equivalent to the other members of the University staff." It might have stated that there were about fifteen professors whose salaries equal that of the Dean of the Faculty of Applied Science and Engineering. In other words, a Professor of such subjects as Latin, Greek, History, Geology, Bio-chemistry, or Physiology, draws a salary equal to that of the Dean, even although the latter has spent nearly thirty-five years of service in the School. It might also have been mentioned that among these and other professors there are those who conveniently can, and do, engage in various remunerative duties not pertaining to the University.

The Past Presidents' Association of the Engineering Society brought to the attention of the Board of Governors of the University the desire of a graduate body of the School to have more recognition shown the Dean, in his position as head of this Faculty. The Board of Governors, however, stated that an adjustment of the matter was impossible owing to the present financial condition of the University.

The graduates should inform themselves of the actual figures as contained in the "blue book" pertaining to University affairs—the annual report of the Board of Governors. They should thresh out the matter pro and con, and if it appears advisable, they should take up the good work of the Past President's Association, so that a request representative of the entire body of School men might be presented to the Board of Governors sometime during the coming winter.

QUALIFICATIONS OF INSPECTORS

This is concerning a recent item in the daily press about a municipal engineer, a graduate of the school, who has for some time obtained satisfactory service from younger school men as inspectors on his various classes of municipal work. A member of the town council objected to the employment of these men. He intimated that a rate-payer should be given the prefer-

ence. He even suggested that the engineer be requested to make the change on his various jobs.

Whether the complainant has personal designs for the mayorality chair or whether his request merely stated his conception of the requirements of an inspector, we will leave alone. We did not note what action the Council took. Our men are still pursuing their work as inspectors and we hope to have the pleasure of filling any vacancies that may arise on the same engineer's staff of men.

Is it possible that a man, elected to safe-guard the interests of a municipality, should hold such a flimsy opinion of the value of a good inspector on engineering work? It simmers down to a question of that alone. "School "men, with a clear conception of specification requirements and with a keen appreciation of the responsibility of their position—and generally with considerable previous experience, are the best available men for such work. This statement is borne out by the fact that the demand for them far exceeds the supply. Not that it is the most suitable line of employment for the young engineer starting out in the profession, but when it is a question of the best man for the position at the usual salary, rather than one of keeping the corporation's money in circulation among its rate-payers, the "school" man is showing himself to be the man of greatest value.

A RECORD OF OUR MEN

Of the forms sent out to all graduates during the month of May for return to this office, giving information regarding their professional work, some 367 have been received. A number of older ones are also on file, totalling responses from about one-third of the graduate body. This is not sufficient for the efficiency and usefulness aimed at. If we can establish and maintain in index form a data sheet of the professional work of every school man, susceptible to easy reference, comprehensive and reliable, it will form a volume of most valuable information for the Engineering Alumni and for the University as well. These data sheets are filled out in this office from the information the graduate sends us on the "graduate form." This is done to maintain uniformity in the series, and to properly classify forms according to the man's professional experience.

One can conceive of a dozen distinct advantages of having such a record, providing it is complete. It will facilitate in many ways the clerical work around the University pertaining to graduates. It will afford a ready means at any time of one school man locating and familiarizing himself with the work of his class mates. It will prepare in usable form a strong instrument for the graduate body to employ should the occasion arise for their mustering ideas and forces in the interests of the School. It will also be indicative of what the Institution has accomplished in its 34 years of operation.

But a representation of one-third of the graduates is not sufficient for any such purposes. The more complete our record is the

more of value it will be. Look up the circular letter sent out last May and return the enclosed "graduate form," well filled in.

A number of positions are open for applicants. There are several in mining, a few in electrical work, as many in architectural work, and a goodly number of vacancies in drafting offices, especially on structural steel work. If out of employment or contemplating a change, we will be pleased to supply addresses. If you have not sent us a record of your experience—let it accompany your application.

EMPLOYMENT

AT THE OPENING OF GILLIES' LIMIT

In the recent rush to the newly-opened 4000 acre portion of what is well known in mining circles as Gillies' Limit, a region south of the town of Cobalt, purported to be rich in mineral wealth, we note the names of a few of our "School" men standing prominently among these of the host of veteran prospectors bent on staking the best available claims.

The limit was thrown open at midnight, of August, 19th, and nearly 2000 prospectors were there to stake less than 200 claims. In less than thirty minutes the spot was again practically deserted and the excitement had subsided into an individual hustle for the recording office in Haileybury. The second man to reach the office was Angus Campbell, '10, and in a few moments, Lee Stitt, '15, appeared, to be closely followed by Bert Neilly, '07, whose special train had met with a slight delay at Cobalt. C. G. Titus, '10, and A. D. MacDonald, '11, were also in the line-up, and, as usual when School men are drawn together, the renowned Toike Oike was in evidence, according to the local press, and enlivened the long wait for the opening of the recording office door at 8.30.

WHAT OUR GRADUATES ARE DOING

Chester B. Hamilton, '06, manager of the Hamilton Gear and Machine Co., Toronto, is completing the erection of a concrete annex to his plant, doubling the capacity of his tool rooms and machine shop.

F. T. Nichol, '10, with Clarence W. Noble, Contracting Structural Engineer, is engaged at present in the Montreal office. A. E. Nourse, '07, the representative of the firm in Montreal, is seriously ill in the hospital with typhoid.

D. W. Harvey, '09, who has for some time been resident engineer on the St. Clair Avenue Civic car lines, Toronto, has recently been appointed engineer-in-charge of the civic car lines to succeed A. E. K Bunnell, '06. Mr. Bunnell has accepted a position as engineer-in-charge of construction on the Lake Erie & Northern Railway from Brantford to Galt.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 24 TORONTO, SEPT, 1912 New Series Vol. VI, No. 5

THE SYNTHESIS OF AMMONIA

By J. W. Scott, B.A.Sc.

Ammonia is found widely distributed in nature. It occurs in the atmosphere forming a small but essential constituent of the air; likewise in many soils, sea clays, marls, ochres, in almost all plants, in the excrements of many animals and among the products of decay of nitrogenous organic bodies. It is also found in combination with acids as a salt in many parts of the world, deposited on the sides, the crater, crevices and in the lava of active volcanoes, in rain water and in the fumaroles of Tuscany.

The word "ammonia" occurs in two entirely different meanings. With one of these, the "gum ammoniac," we will not deal here. The other meaning of "Ammoniakon" or "Sal Ammoniacum" is that which we now connect with the word "Salammoniac." The word "ammoniakon" occurs in the first meaning already in the writings ascribed to Hippocrates, and dating from the fifth century before Christ; also in those of Pliny, Dioscorides, and other authors of the classical times, as well as later on in the writings of mediaeval Arabians and Europeans. Herodotus speaks of "hals ammoniakos," but he evidently means the crystallized rock salt (sodium chloride) of the Ammonian Oasis, and so do all the following Greek and the later Syrian and Arabian authors, up to the sixth century of our era.

In the second meaning, that which we give to the word "sal ammoniac," we find that word in Pliny, who rather indistinctly speaks of it as sometimes occurring in Egyptian "nitron" (natural soda). A more accurate knowledge of it dates only from the development of the process of sublimation and distillation in Egypt, say, about the fourth century after Christ, since it was evidently observed when burning camel dung in fireplaces provided with a chimney. The Arabian polyhistor Al-Gariz mentioned sal-ammoniac as one of the matters well known to have been obtained by the Arabs from the Greeks, by the Persian name "nashadir," which is found in various other Arabian and Persian authors later on.

Ammonia was known to the early alchemists in the form of the carbonate under the name of "spiritus salis urinae."[1] In the

1 "Roscol and Schorlemmer"—Treatise on Chemistry.

fifteenth century it was known that the same body might be obtained by the action of an alkali upon sal-ammoniac, and Glauber, in consequence, termed this body "spiritus volatilis salis armoniac." Sal-ammoniac which was known to the Latin Geber, appears to have been brought in the seventh century from Asia to Europe, and was known under the name of "sal-armoniacum." In later times sal-ammoniac was brought into Europe from Egypt where it was prepared from the soot obtained by burning camel's dung. Its original name was altered to "sal-ammoniacum." This last name served originally among the Alexandrian alchemists to describe the common salt and native sodium carbonate, which were found in the Libyan desert in the neighborhood of the ruins of the temple of Jupiter Ammon. Later on sal-ammoniac was obtained by the dry distillation of animal refuse such as hoofs, bones and horns: the carbonate of ammonia thus formed being neutralized with hydrochloric acid. From this mode of preparation ammonia was formerly termed "spirits of hartshorn."

Up to the time of Priestly ammonia was known only in the state of aqueous solution termed "spirits of hartshorn" or "spiritus volatilis salis ammoniac." Hales in 1727 observed that when sal-ammoniac is heated with lime in a vessel closed by water, no air is given out, but, on the contrary, water is drawn into the apparatus; Priestly in 1774, repeated this experiment, with the difference, however, that he used mercury to close his apparatus. He thus discovered ammonia gas to which he gave the name "alkaline air." He also found that when electric sparks are allowed to pass through his alkaline air, its volume undergoes a remarkable change, and the residual air was found to be combustible. Berthollet following up this discovery in 1785, showed that the increase of volume which the ammonia gas thus undergoes is due to the fact that it is decomposed by the electric spark into hydrogen and nitrogen. This discovery was confirmed and the composition of the gas more accurately determined by Austin (1788) Davy (1800) and Henry (1809). It was shown by them, that in the reaction above described, two volumes of ammonia are resolved into three volumes of hydrogen and one of nitrogen.

The chief sources of ammonia are: The distillation of coal for gas or coke, of bituminous shales and of bones and other animal matter; putrid urine; the residues of the beet sugar industry and those left after the fermentation of molasses for alcohol; and the waste gases from blast furnaces.

At the present day almost all the ammonia and its salts are prepared from the ammoniacal liquor which is obtained as a by-product in the manufacture of coal-gas. Coal, as we know, consists of the remains of an ancient vegetable world, and contains about two per cent. of nitrogen, the greater part of which, in the process of the dry distillation of the coal carried on in the manufacture of the gas, is obtained in the form of ammonia dissolved in water along with other products formed at the same time. Chief among which are ammonium carbonate, sulphide, sulphite, sulphate, thiosulphate,

sulphocyanide and ferrocyanide. This aqueous solution is then distilled with lime and the free ammonia obtained.

On account of the great technical value of ammonia and because nitrogen compounds are an essential constituent of all living matter, various attempts have been made at synthesising ammonia.

Probably the first man to attempt this synthesis was Donkin, who attempted to produce ammonia by passing an electric spark through a mixture of three volumes of hydrogen and one volume of nitrogen. This process is unsuccessful due to the small yield of ammonia obtained, as 94-98% of the ammonia formed is decomposed back into its elements and only 2-6% union of the constituents occur under the same circumstances. This is due to the heat formed by the electric spark.

The ammonia equilibrium is attracting much attention at the present day, as several well known chemists are still investigating this problem.

F. Haber and G. Vanoordt,[1] who have been interested in this problem have done some splendid work upon it. A current of pure ammonia was led over finely divided iron kept at a temperature near 1000°C. The decomposition products were freed from the undecomposed ammonia by leading them through standard acid, then led over a further quantity of finely divided iron and the amount of ammonia reformed was determined. The iron was prepared from iron oxalate in a current of ammonia and was supported on asbestos in the heating tube. Some experiments were also made with fairly divided nickel supported on silicic acid with nickel nitrate and igniting in a current of hydrogen, but the metal proved a less effective catalyst than iron. The results obtained show that equilibrium is attained from both sides.

$$3\ H_2 + N_2 \rightleftarrows 2\ N\ H_3$$

Exp.	Catalyst.	Residual gas at O° & 760 mm. consisting of N2 & 3H2 liters.	Parts of ammonia decomposed per 1000	Parts of ammonia formed per 1000	Temp.
1	Iron	14.509	<—— .08 ——	——>	1057 + or — 23 (*)
2	"	17.948	<—— .46 ——	——>	1037 + or — 17
3	"	15.706	.20	.26	1029 + or — 19 (— 10)
4	"	16.530	.21	.14	1010 + or — 10 (+ 15)
5	"	13.786	.23	.16	1009 + or — 6 (— 4)
6	"	16.863	.15	.14	1016 + or — 4 (+ 9)
7	"	11.380	.20	.21	1013 + or — 17
8	Nickel	12.173	.25	.11	1024 + or — 18
9	"	12.359	.485	.272	1020 + or — 4

* Lower temp. at the beginning of Exp.

In experiments 1, 2, 8 and 9, the two tubes containing the catalyst were arranged in the same heating tube, but in experiments 3, 4, 5, 6 and 7, two heating tubes were used. The figures in the brackets give the variation of the temp. of the second tube from that of the first.

From the results of experiments, Haber and Vanoordt have calculated the free energy of the formation of ammonia and have

1 Z. Anorg. Chem. 1905 or J. Soc. Chem. Ind. 1905.

deduced the following values for the amounts of ammonia contained in mixtures of N_2, H_2 and NH_3 in equilibrium at 760 mm. pressure and temperatures given.

27°C	– 98.51%
327°C	– 8.72%
627°C	– .21%
927°C	– .024%
1020°C	– .012%

These figures show that in the synthesis of ammonia in order to obtain results of technical value, a catalyst is needed which will act satisfactorily at a temperature not much above 300°C.

Haber and a student of his, R. LeRossignol,[1] pursued this question further. They investigated the equalibrium

$$2NH_3 \rightleftarrows N_2 + 3H_2$$

at various temperatures in continuation of previous experiments at 1000°. The method consisted in passing dried ammonia through quartz or glazed porcelain tubes heated in an electric furnace. The temperature was measured by means of a thermo-element. As catalysing agents metallic iron, nickel, chromium and manganese were used. The gases were passed through standard hydrochloric acid and the unchanged ammonia determined by titration. The unabsorbed hydrogen and nitrogen were then passed through a second tube, where a reverse action occurred. The newly formed ammonia was determined as before. The residual hydrogen and nitrogen were measured and samples analysed. The equilbrium constant from the expression

$$\frac{P_{NH_3}}{P_{N_2} \times P_{H_2}} = K_P$$

was determined for the following temperatures

Temp.	$10^4 K_P$
1000	1.48
930	2.0
850	2.79
800	3.34
750	4.68
700	6.8

The ratio of unchanged ammonia to ammonia taken, was somewhat less at 1000°C than Haber and Van oordt previously found, and totalled from 1.1 to 2.5 ten-thousandths. The position of equilibium was not so greatly altered by lower temperatures, as had been calculated from Haber and Vanoordt's experiments.

Nernst's expression, $\log K_P = \frac{12000}{4.571T} - 175 \log T - 1.3$

1. Chem. Abstracts, 1907.

may be altered to agree well with the experimental results by adding to the right hand side a member derived from the mean specific heat of ammonia under constant pressure.

Due to a disagreement between Haber and Nernst, as to the relative concentrations of the reacting gases at the point of equilibrium, Nernst maintaining that at atmospheric pressure the amount of ammonia is too small to be accurately determined, Haber and LeRossignol have performed a large number of experiments employing pressures of thirty atmospheres. The equilibrium was reached from both sides. The results obtained at thirty atmospheres pressure are in full accordance with those previously obtained at one atmosphere. The reaction tube consists of transparent quartz. Up to temperatures of 1000° the loss due to diffusion of the gases through the walls of the tube was negligible. The catalyser was finely divided iron or manganese. At 901°C and 30 atmos. the equilibrium value for the concentration of ammonia was found to be .206% by volume, a mean value of a large number of determinations. At 801° and under the same pressure .334% ammonia was found and at 700° .65% ammonia. In all of the experiments the original gas consisted of either ammonia or wholly dissociated ammonia or a mixture of three volumes of hydrogen and one of nitrogen. The results are not in harmony with those of Nernst.

Nernst disagreed with Haber over the equilibrium of the reaction $N_2 + 3H_2 \longrightarrow 2NH_3$ consequently the equilibrium was investigated anew. According to the reaction $2NH_3 \longrightarrow 3H_2 + N_2$, high pressure will tend to increase the output in ammonia. A porcelain tube furnace incased in an iron pipe was used and pressures of 12 to 70 atmospheres were applied. The reaction gases were passed over platinum foil, which acted as catalyser, and from the further end of the tube passed through a fine porcelain capillary. The speed of the gas mixture could be regulated at will. The temperature ranged between 685° and 1040°. The ammonia content was determined by analysis. The experimental values agree very well with the theoretical. The heat of reaction Q (for $2NH_3$) was found to be 28020 cals. a value somewhat higher than that determined by Thomson or Berthelot, but in good accordance with the theoretical value. Haber and LeRossignol's results for the equilibrium at atmospheric pressure do not agree with those of Nernst and Jost, as Q was found to be 24,000 cals. Nernst maintained that the output at atmospheric pressure was too small and inaccurate to base any conclusions upon it. Nernst's results are of technical interest in so far as they show that the ammonia output at high temperatures is only one-third of what has been expected on the bases of Haber's figures.

F. Jost who worked with Nernst, carried out experiments using a furnace as above described, and temperatures of 685° to 1040°. An equilibrium was reached from both sides, first by passing a mixture of one part of nitrogen and three parts of hydrogen at a pressure of 50 atmospheres, through the furnace and determining the amount of ammonia formed, and secondly, by passing a similar mixture

containing 20% ammonia and determining the amount of ammonia present. The results of a series of measurements agree satisfactorily and can be expressed by the formula:

$$\log X = 3065T - 6.918$$

where X is the partial pressure of ammonia formed from a mixture of three parts of hydrogen and one of nitrogen at a pressure of one atmosphere. Thus at 1000°, X was found to be 0032% while the above formula gives X = .00308%. By means of Van Hoff's isochore the heat of reaction was calculated to be 28000 cals. as against a value of 24000 cals. as found by Thomsen and Berthelot.

Nernst points out that known volumes of two gases were passed successively at the same rate through a copper tube containing silver shavings and then through a small silver calorimeter placed completely inside an electric furnace. The copper tube projected some distance into the furnace owing to radiation, etc. Its temperature was measured very accurately and was found to be 200° lower than that of the calorimeter when stationary conditions had been reached. The comparative amount of cooling produced in the calorimeter by the passage of the various gases was measured by means of a differential thermo-element, the second junction of which was situated in the internal copper lining of the furnace. The heat change corresponding to the reaction $3H_2 + N_2 = 2NH_3$ at 850° is 30200 cals. with an uncertainty of 1500 cals. This is close to the value 28000 cals. calculated from the measurements of Jost, but is far from 25000 cals. calculated by Haber and LeRossignol.

From the above we see the ammonia equilibrium is far from settled. Now turning aside from the physical aspect of the subject, let us look into some of the processes devised by numerous inventors. We may, as L Mond suggests, divide the processes of this kind into three classes:

1. Processes which aim at the combination of hydrogen and nitrogen at high temperatures; or with the assistance of electricity, or in the presence of acid gases.

2. Processes in which primary nitrides are formed, which are afterwards transformed into ammonia.

3. Processes in which primary cyanides are formed.

With this division in view it is the writer's intention to describe one or two of the more promising processes in each division, with a special stress on sub-division 1

Several inventors aim at utilizing the intervention of the boron nitride for forming ammonia. Thus N. Basset heats coal impregnated with boric acid, and covered with a layer of magnesia, lime, oxide of manganese, etc., in a retort, and passes nitrogen over the mixture. When a sufficient quantity of boron nitride has been formed, steam is introduced, and the ammonia now obtained is carried away.

G. N. Tucker mixes carbon, impregnated with borates, with alkaline carbonates, or the oxides of manganese, antimony, iron, titaniferous iron, or with the borates of these metals. These are

exposed to a red-heat in retorts; gas rich in nitrogen is passed in, so that the nitrogen combines with boron; then steam is passed in, which is decomposed by the carbon or the metal, and supplies the hydrogen necessary to form ammonia, or else air or nitrogen and steam are mixed before introducing into the retort, in the proportion of 3 vols. steam to 1 vol. of nitrogen. The borates and the metallic oxides contained in the residue are to be used over again. The gas is purified, by milk of lime, from carbonic acid, hydrogen sulphide and tarry substances.

Mond believes that boron nitride cannot be utilized for the purpose in question, owing to the high temperature required for its formation and the volatility of boric acid with steam. More success seems likely to be obtainable by Lessie du Motay's plan of preparing titanium nitride, and allowing a mixture of nitrogen and hydrogen to act upon this. Titanium forms two nitrides, the higher of which is at high temperatures reduced to the lower by hydrogen, with the formation of ammonia. When passing a mixture of hydrogen and nitrogen over the higher titanium nitride, Mond never obtained so much ammonia as would be formed without any free nitrogen. Hence the lower nitride does not combine with more nitrogen, which makes the process impossible.

Kaiser obtains ammonia by heating calcium nitride in a current of hydrogen under high pressure; the calcium is reduced to the metallic state, or to the hydride when the hydrogen is in excess. If now nitrogen is passed over it calcium nitride is reformed. A continuous production of ammonia can be effected by heating metallic calcium alternately in a current of nitrogen and hydrogen. This takes place all the more readily when the metal is deposited on asbestos in a finely divided state. The reaction sets in at about 150°C; the best results are obtained between 200° and 400°C.

Borchers and Beck prepare nitrides of metals from atmospheric nitrogen by the assistance of the electric current in a similar way, as in the electrolysis of alkaline chlorides, where the cathodic mercury is charged with alkaline metal, which is taken out of it, so that the mercury can be used over again. An alloy of tin and magnesium electrolytically formed, is by the action of nitrogen in another space partially converted into magnesium nitride; the alloy now containing much less Mg, returns to the cathode space to be again enriched with Mg. The magnesium nitride is converted into ammonia by means of water or of steam, and the process may be conducted in such manner that anhydrous ammonia and anhydrous MgO are formed. The latter is used over again in the electrolytic cell.

J. Lipski[1] says that in his process of using cerium nitride the yield of ammonia is considerably greater than has hitherto been obtained by similar processes, the volume of ammonia in the gas stream easily reaching one per cent.

$3H_2 + CeN \longrightarrow CeH_3 + NH_3 \quad ; \quad N_2 + CeH_3 \longrightarrow CeN - NH_3.$

The above takes place at atmospheric pressure and at low

1. Z. Electrochem. 1909, or J. Soc. Chem. Ind. 1909.

medium temperatures without interference from the reaction,

$$3H_2 + 2CeN \rightleftharpoons 2CeH_3 + N_2$$

although at high temperatures, when the dissociation pressures of the nitride and hydride are greater and the stability of ammonia is small, the last reaction predominates; the temperature most favorable to the formation of ammonia by this process is 200° — 300°C. The gases must be pure and dry, traces of moisture affecting the surface of the material and rendering it useless. By employing nitrogen and hydrogen alternately a continuous production of ammonia takes place.

Having executed the work of ammonia synthesis from the nitrides of metals, let us discuss the formation of it from the cyanides or carbides. As was the case in the nitrides, much work has also been done on this branch of the subject and many inventors have patented their discoveries.

In 1860 Margueritte and Sourdeval found that caustic baryta is very active towards nitrogen, because it is neither fusible nor volatile. The former quality prevents the external fusion of the mass, whereby the action of the gases on the interior is impeded; the latter prevents loss by volatilization.

$$Ba\,(NC)_2 + 4H_2O \longrightarrow 2NH_3 + Ba\,(OH)_2 + 2CO$$

They made a mixture of native barium carbonate with coal tar, pitch and sawdust, with or without iron filings, which was strongly ignited in a fire-clay retort till the barium carbonate had been converted into a porous mass of barium oxide Through this they passed at the proper temperature a slow current of air, the oxygen of which had been previously converted into carbon monoxide by red-hot coal, thus barium cyanide was formed. This was cooled down to 300° and steam was passed through. All the nitrogen of the cyanide is evolved as ammonia, and the barium hydrate remaining behind may be used over again. This process did not pay owing to technical difficulties.

Margueritte and Sourdeval's process was taken up again by L. Mond who carried it out in the following form. The barium carbonate is powdered and incorporated with small coke from pitch or oil residues, charcoal, pitch, tar, paraffin residues, and so forth. In lieu of barium carbonate it is possible to employ a solution of its oxide or salts, or of alkaline oxides or salts; for instance the solution obtained by lixiviating the used briquettes. The most advantageous proportions are; Thirty-two parts barium carbonate, eight parts of charcoal or coke, and eleven parts pitch. The addition of alkalies is not of much use. This mixture is formed into briquettes, which it is necessary to heat in the reducing flame till the pitch is coked, and the barium carbonate converted partially or completely into oxide. The briquettes may be broken up into small lumps, and such lumps may also be formed by heating the mixture of barium carbonate or carbon on the hearth of a reverberatory furnace or in a revolving furnace by means of a reducing flame until the mass is fritted, when it is discharged and broken up into lumps.

These lumps or briquettes are charged into kilns arranged in the same way as an annular kiln, so that some of the chambers are being heated while others are cooling down, or are being filled or emptied. A gaseous mixture, as rich as possible in nitrogen, and containing little carbonic acid, oxygen and aqueous vapor, heated to a temperature of about 1400°C., is passed into the chambers filled with briquettes, until a sufficient quantity of cyanogen compounds has been formed. When this is the case, the stream of heated gas is shut off, and cold gas of the same or similar composition conducted into the mass until the temperaure has fallen to 500°C. The stream of gas is now suspended and the material treated with steam; the ammonia hereby resulting, is aspirated off and absorbed or condensed. As sources of nitrogen, the gases evolved from the carbonic acid absorption apparatus of the ammonia soda process, and the gaseous mixture obtained by the combustion of coal or coke with the smallest possible quantity of hot air, are the most profitable; and the requisite temperature is most readily obtained by means of a Siemens recuperatorm applying this also to the previous heating of the air employed for the combustion. The gases leaving the last chamber, which is being heated at the time must be further cooled down by passing them under a boiler or pan, or through a washing apparatus, before they get into the chamber where the material is just cooling. After having fulfilled this object, these gases, which contain much carbon monoxide, may be burned and used as a source of heat, for instance, for heating air, generating steam, and for other purposes.

This process, although tried on a somewhat large scale, did not come into practical operation. The process requires a very large amount of heat to be communicated through the earthenware sides of a retort, which wastes too much fuel, even if retorts similar to those of zinc works are employed. This cannot pay whilst so many other sources of ammonia are available.

Herman Mehner[1] has however, devised a long and drawn out unique process for the production of ammonia from cyanides. His invention has for its object the improvement of the process of manufacturing nitrogen compounds from atmospheric nitrogen, producer gas or other suitable gaseous mixtures by having them react with carbon in the presence of alkaline matter, such as hydrates and carbonates of alkaline and alkaline-earth metals, also to do away with loss of heat due to radiation, etc. He causes the mixture of carbon and an igneous fluid heat-carrier, such as molten salts, as silicates, preferably alkaline silicates, scoria, slag, cinder and other suitable compounds or salts, and also molten metals, as iron and the like, to percolate through in the presence of alkali. Air or other suitable gases containing nitrogen are allowed to penetrate through at an intermediate zone in the furnace. The current of air is subdivided in the furnace into a strong upward and a weak downward current. By this the furnace is divided into an oxidizing zone, a reducing zone and a reacting zone. The oxidizing zone is the upper one, where owing to the larger supply of oxygen the combustion will substantially result

1. U. S. Pat. No. 754474 of 1904.

in carbonic acid, and consequently a correspondingly large amount of heat is produced, which is taken up by the percolating heat carrier, the carbonic acid escaping through an opening. The reducing zone is the one below the oxidizing zone, where as a consequence of the smaller supply of oxygen, the carbon is burned only to carbon monoxide. The heat generated is added to that of the heat carrier, and both supply the zone below with the necessary heat for the reaction, and moreover, the lowest zone is held free of any carbonic acid gas thus preventing the cyanide reaction from being disturbed. The slag returns to the top of the furnace and repeats the percolation.

The furnace resembles a shaft furnace provided at the top with a hopper for supplying carbon and a vessel for supplying the molten slag. A lid, which is sealed by a sand seal, closes in the hopper. The furnace is filled with coke, divided into suitable pieces. About the middle of one side of the furnace is the tuyere for admitting the hot air and an arrangement to divide it into two currents as above described. The molten slag then percolates through and is removed at the bottom to repeat the operation. In this process incandescent coke, nitrogen and sodium vapors, obtained from the slag, are brought into intimate contact with each other in the presence of such catalysts as iron, etc. Thus, sodium or alkaline cyanides are formed which are converted into ammonia by means of steam.

The Method of the Synthesist.

Let us now say a few words in regard to the synthesising of ammonia from its elements, namely nitrogen and hydrogen. This is accomplished in several ways, such as the use of a catalyst, the silent electric discharge and so on.

E. P. Perman states that ammonia cannot be synthesised from nitrogen and hydrogen by the action of heat alone; the decomposition of ammonia by heat at 800–1000°C. is therefore irreversible. Synthesis may be accomplished (in small quantities) when the gases are partially ionised, as by sparking them, or by exploding them with oxygen, or by heating them with many of the metals in the presence of moisture.

Many inventors have worked upon this principle, some succeeded in getting fair results while others were not so good. Upon diagnosis of this case I have decided to describe a few of the processes now in use.

Haber and Le Rossignol have now discovered that on passing gases containing nitrogen and hydrogen over osmium large quantities of ammonia can be obtained.

In order that this process should be successful, it is advisable that the combination take place at as low a temperature and as quickly as possible, since when the temperature increases the concentration of the ammonia formed decreases.

In carrying out this invention, osmium can be used either in the form of the metal, in a very finely divided condition, or in the form of a compound of the metal, which on being used becomes converted into metallic osmium, such as, for instance, osmium oxide hydrate,

(prepared by the reaction of formaldehyde on an alcoholic solution of osmic acid), or as Fremy's salt.

The osmium is precipitated on a suitable carrier such as quartz, asbestos, clay and so on.

At 200 atmospheres pressure, and in the presence of suitable contact substances, nitrogen and hydrogen combine to form ammonia in sufficient quantity for practical exploitation of the process. The reaction is very incomplete, and it is necessary to remove the ammonia as it is formed, which can be achieved by a system of circulation of the gases at high pressure. The ammonia is condensed and can be removed either as a gas, or as anhydrous liquid; the uncombined gases continue to circulate throughout the high pressure system. In a small experimental apparatus, built at the Karlsruhe Institute for Physical Chemistry, 90 grams of liquid ammonia were produced per hour at 185 atmos. pressure. Osmium is the most active contact material for this purpose, at 175 atmos. pressure and temperature of 550°C. yields of 8 volumes per cent of ammonia can easily be obtained from the mixed gases of 1 vol. of nitrogen and 3 vols. of hydrogen.

As the amount of available osmium is very small, another more easily obtainable catalyst was sought for and was found in the form of uranium containing a certain amount of carbide, or carbon, as obtained by the reduction of the oxide with carbon in the electric arc. In the gaseous mixture at high pressure this is transformed into a very fine powder, with the absorption of nitrogen, and this power exerts a powerful catalytic action of the gaseous mixture at a temp. below 500°C. The power necessary for compression and circulation of the reacting gases is very small. The efficiency of the heat exchange appears to be of subordinate economical importance, and the industrial exploitation of the process may soon be looked for.

L. Brunel and P. Woog,[1] after unsuccessful efforts in the formation of ammonia by passing a mixture of pure hydrogen (3 vols.) and nitrogen (1 vol.) over thorium and cerium oxides, palladinised pumice, quicklime, soda lime, calcium chloride, calcium molybdate, anhydrous barium or strontium oxide, manganese dioxide, aluminium phosphate or magnesium phosphate, at 15° to 350°. However, green nickel oxide hydrated spread thinly over fragments of powdered glass, is heated in a current of dry air and a mixture of hydrogen and nitrogen is then passed over the sesquioxide thus formed, heated to 180°–200°C. A small amount of ammonia and water is formed, on the passing a mixture of air and excess of hydrogen, the nickel oxide is alternately reduced and reoxidised with evolution of much heat, and a continuous formation of ammonia and water results so long as the temperature is kept below the incandescence of the oxide. The requisite cooling is effected by suspending the nickel oxide in a liquid which boils at the temperature at which ammonia is formed and thus absorbs the excess of heat. Petroleum B.P. 200°–240°C. is found to answer this purpose and by its intervention a regular formation of ammonia is obtained.

1. J. Soc. Chem. Ind. 1907.

H. C. Woltereck states that ammonia is always formed when a mixture of pure hydrogen and nitrogen is passed over reduced iron heated to a dark red heat. This formation, however, soon ceases, and a careful study of the conditions has demonstrated that the formation was due to the presence of oxygen in the form of iron oxide, since iron freshly reduced by hydrogen and not exposed to the air will not produce a trace of it. Careful experiments have shown that the presence of oxygen is essential to the formation of ammonia, and that the contact material employed must be able to act as a carrier of oxygen.

When a mixture of 3 vols. of hydrogen and 1 vol. of nitrogen is passed over reduced iron, spread in thin layers on asbestos fibre, and heated to 550°C. small quantities of ammonia are formed. The yield is increased by the oxide of the metal, but in both cases the yield stops after a time. Similar results are obtained with the oxides of nickel, cobalt, cadmium, silver, lead, bismuth, chromium, the last two giving the best yields. The reaction is made continuous by replacing the nitrogen by air, and the results are improved by the introduction of water vapor, whilst the hydrogen can be replaced by coal gas freed from nitrogenous products. The passage of 100 liters of a mixture of hydrogen (one vol.) and air (78 vols.) through water kept at 80°C. and then over iron oxidised and reduced by carbon monoxide, before the experiment, gave at different temperatures the following amounts of ammonia:

260 – 800°C.	.0803 gm.	400 – 450°C.	.0134 gm.
300 – 350°C.	.204 gm.	450 – 550°C.	.0411 gm.
350 – 400°C.	.119 gm.	550 – 650°C.	.0236 gm.

All the experiments occupied 4.5 hours. The results show that 300–350°C. is the most favorable temperature. Diminishing the velocity of the gas, i.e., prolonging its contact with the iron, diminishes the yield. Other oxidisable materials which can be substituted for the reduced iron are coke and wood charcoal, but better results are obtained from peat. A series of comparative experiments using sugar charcoal, and varying the temperature, the volume, and the velocity of the mixed gases, show that the best results are obtained at 450°C. with 40 1. of gas passing 6 hours when .9 gm. of ammonia was formed per 100 gms. of charcoal burned.

E. Briner and E. Mettler form ammonia from its elements by the action of the electric spark, at the temperature of liquid air. A mixture of 3 vols. of hydrogen and one vol. of nitrogen was introduced into a flask fitted with platinum electrodes and a spark passed across the electrodes. In order to avoid the decomposition of the ammonia formed, they cooled the flask with liquid air, thus liquifying the NH_3 formed. With this device it was found that the yield of ammonia increases with the intensity of the primary current up to a certain point and then decreases. For example, with a current intensity of 1.7 amps. the yield of NH_3 was 25 mgrs. per kw. hr., while with 2 and 2.6 amps. respectively the corresponding

values were 55 and 42 mgrs. They state that the silent electric discharge gives better results than the spark discharge at the temperatures of liquid air. Other experimenters add a little of some acid to their mixture of N_2 and $3H_2$ to remove the ammonia as it is formed, in order to do away with the cooling of the flask. The authors state that working with a pressure of 100 mm. of mercury they obtained their best results.

Nithack has a very nice apparatus for the production of ammonia. He saturates water under high pressure with gaseous nitrogen and then passes electricity through the water. He states that the nitrogen is quantitatively transformed into ammonia.

Although these processes above described are very interesting, yet while the ammonia from the gas works is obtained in such copious quantities, these methods are not yet working on a commercial scale, and we must wait until some easier and cheaper method is devised until we are able to complete with the ammonia, which is obtained as a by-product from the gas works.

In the describing of the above processes, the writer has only dealt with those experiments which give hope of practical exploitation of this subject.

In the Laboratories of the University.

Let us now turn to the writer's experiments upon this problem. An attempt has been made to synthesise ammonia from its elements in several ways, namely, by the use of a catalyst, the bringing together of nitrogen and nascent hydrogen, and by the reduction of nitric acid.

Figure 1 will show the apparatus used by the author for the bringing together of nascent hydrogen and nitrogen. It consists of a glass spiral, through which a platinum wire runs. The platinum wire is supported on glass beads at close intervals, this was to enable the wire to be forced around the spiral, and at the same time to keep it away from the walls of the tube. This wire was made the cathode of the cell, while the anode was a lead strip. The electrolyte was dilute sulphuric acid.

By means of a delivery tube nitrogen from a gas holder was made to bubble around this spiral and when the current of 220 volts and ½ amp. was run through this, electrolysis commenced. By this method the nitrogen came in contact with the nascent hydrogen liberated from the wire.

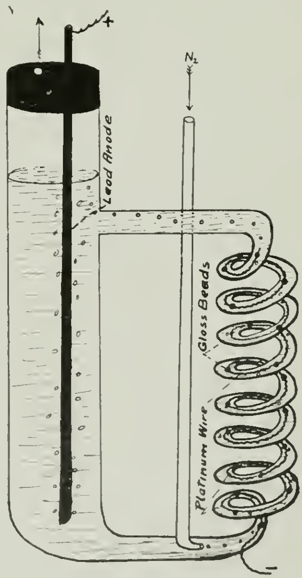


Fig. 1
Apparatus for Combining Nascent Hydrogen with Nitrogen.

This experiment proved fruitless, as hydrogen was not liberated from the whole of the wire, but just from about ½ inch of the wire

which was nearest the other electrode. In this manner the nitrogen did not have a fair chance for its combination.

A lead spiral was substituted for the glass one, and the whole spiral was made cathode, while the anode was lead, the electrolyte as before being dilute sulphuric acid. Nitrogen was introduced in a similar manner as above described. Here also the experiment gave no evidences of any ammonia having been formed, when tested with Nessler's solution.

During the electrolysis the whole apparatus was immersed in a pail of cold water to prevent the apparatus from becoming too hot and thus cracking.

In all these experiments the nitrogen used was made by making a saturated solution of 1 part of sodium nitrite and 1½ parts of ammonium sulphate and by mixing these in a flask, to which a little potassium bichromate has been added in order to oxidise nitrous fumes, a nice gentle stream of gas can be obtained which should be washed, through dilute sulphuric acid to remove nitrous fumes, before being used.

Another scheme attempted by the author for bringing nitrogen in contact with nascent hydrogen, was the use of a porous graphite tube, which was to act as cathode of a cell, while nitrogen was forced through the tube, and allowed to diffuse through the pores, and thus come in contact with the hydrogen liberated from the acidulated water, which was to act as electrolyte. This attempt failed, in so much as the porous graphite tube could not be made.

Much time was spent in an attempt to produce a suitable porous graphite electrode. Anthracite, coke and bituminous coal were ground to about 20 mesh, and ordinary salt was also pulverized very finely. A mixture of about 80% coal and 20% salt was stirred up to an adhesive mass by the use of various sticky substances such as molasses, engine oil, vaseline, mucilage and glue. This mass was then rammed into a mailing tube, down the centre of which ran a glass tube surrounded by a paper oiled with vaseline. After the tube was filled, the glass tube was easily withdrawn from the mailing tube, on account of the viscosity of its surface, thus leaving a space in the centre of the mailing tube surrounded by the carbon.

The mailing tube was allowed to stand at room temperature for two or three days, then finally dried in the steam oven. After the drying was completed the tube was baked in a muffle, the temperature of which was raised very slowly, for about four hours. The muffle was allowed to cool slowly and the tube removed and placed in a high resistance furnace.

The high resistance furnace was built of magnesia fire brick. The carbon electrodes were buried in crushed coke and the tube placed in the centre of this coke between the electrodes, the whole being covered with coke and finally with bricks. A current of 200 amperes was allowed to pass through this mass for about 2½ hours or until a very bright red heat had been attained, after which the current was shut off and the furnace allowed to cool.

Eight attempts to produce this tube were unsuccessful, after

using various coals and adhesives, as the tubes after placing in the electric furnace no longer held their rigidity, but would fall to pieces as soon as they were touched.

The salt was to be leached out of the tube and thus leave it porous. For future references the writer would call the reader's attention to a paper published in "The Journal of Industrial and Engineering Chemistry," Vol. 1 of 1909, pp. 286, on the "Manufacturing of Carbon Electrodes." This paper treats with the manufacturing of electrodes on a commercial scale, which could not be attempted in the laboratory.

In order to get around this difficulty a lead tube was substituted for the graphite tube. The tube was drilled with several very fine holes, thus making it porous, so to speak. Nitrogen was allowed to diffuse through these holes and thus mingle with the hydrogen liberated.

This experiment also proved fruitless, as the nitrogen could not be kept from spurting out of these holes away from the hydrogen altogether. If the pressure upon it were decreased then a spasmodic spurting would result and no contact could be effected.

The lead tube was finally discarded and the reduction of nitric acid attempted. Figure 2 shows the apparatus used. A quenched copper cathode in the shape of a spiral, and a platinum anode were used. The anode was made by sealing a piece of platinum wire at both ends into a glass tube and then filling the tube with mercury, thus doing away with a great excess of platinum wire.

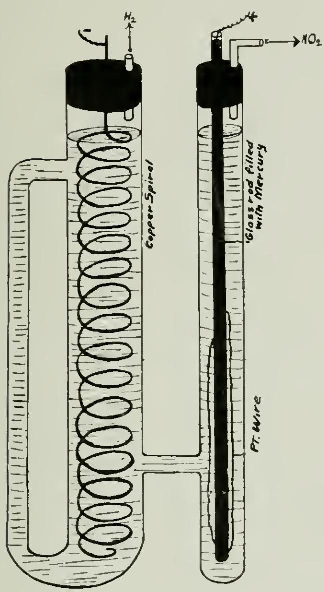


Fig. 2
Electrolytic Reduction of Nitric Acid.

The electrolyte consisted of nitric acid and sulphuric acid in various strengths and proportions.

The experiments were carried out under variable conditions, produced by varying the temperature of the electrolyte and changing the current density. In order to alter the temperature of the electrolyte the apparatus was immersed in water kept at the temperature required.

Julius Tafel[1] points out that when nitric acid is electrolysed, it suffers reduction, and in order to diminish the action of the nitric acid as an electrolyte a relatively large amount of sulphuric or hydrochloric acid was added to the solution. The product of the reduction is largely dependent on the nature of the metals used as electrodes. With platinum no appreciable reduction takes place and with palladium the reduction is extremely slow. The chief

1. Zeit. Anorg. Chem. 31. p. 289-325.

products of the reaction are hydroxylamine and ammonia. The largest proportion for hydroxylamine is formed when mercury is used as the electrodes. With lead electrodes about 40% of the nitric acid is converted into hydroxylamine, and with copper electrodes only about 15%. If the copper be spongy, caused by quenching, only about 1% of the acid is converted to hydroxylamine, the remainder being reduced to ammonia. When an amalgamated electrode is used, the reduction takes place in the same way as when a mercury electrode is employed.

Hydroxylamine is not altered when subjected to electrolysis between copper electrodes. It is thus proved that the reduction of the nitric acid takes place in two ways independent of each other, the one giving hydroxylamine, the other ammonia; the course of the reaction depends on the spedific nature of the electrodes.

The following table gives Tafel's results upon this subject.

2.4 amp. and temp. 0°C.

Cathode material	Surface	Time in hours	NH_2OH	NH_3	HNO_2	gas	sum
Pb.	prepared	2½	26.8	57.6	1.5	7.0	91.4
"	"	2½	25.2	57.6	0.6	8.4	91.2
"	"	2½	22.2	64.6	.3	6.5	93.3
	amalgam.	2½	69.7	16.9	.1	9.2	95.8
Sn.	blank	3	45.8	38.3	.8	7.7	91.8
"	"	3	40.8	42.5	.6	6.9	90.2
Cu.	"	2½	11.5	76.8	trace	7.1	95.4
"	spongy	2½	1.5	93.8	"	..	..
"	"	2½	1.0	92.3	"	3.4	96.7
Ag.	blank	3	18.4	47.2	1.5	21.	86.6
"	"	3	25.3	..	..	18.5	..

In using .4 gm. HNO_3 20 cc. 50% H_2SO_4. 10 sq. dcm. kathode surface.

In the writer's experiments along this line, the current was allowed to pass for approximately 5 hours after which the solution in the cathode compartment was removed and made alkaline by the addition of caustic soda, and then distilled, the issuing gases passed through standard acid. By titration the amount of ammonia formed was determined.

The following table gives the results obtained by the author.

%N H_2SO_4	Gms. 100% [1] HNO_3 used per 200 cc. H_2O	current	time	temp.	gms. NH_3	%
20	3.57	.5 amp.	5 hr.	20°	.415	43.1
20	1.76	.5 "	5 "	20°	.465	97.7
20	3.57	.5 "	5 "	0°	.458	47.5
20	1.76	.5 "	5 "	0°	.460	96.6
30	3.0	.5 "	5 "	0°	.498	87.9

From the results obtained here, the time required to reduce one pound of 70% nitric acid is 905 hours, or 99.5 kilo-watts will be used in the reduction at a cost of 3 cents per k.w.hr. which amounts to $2.98.

1 This 200 cc. of acid was the volume of the cathode solution, being composed of $N.H_2SO_4$ and ½ or ¼N.HNO_3.

As there is not much use for hydrogen at the present time, this by-product will be of little use in defraying the cost of reduction.

From the 318.5 grms. of pure 100% nitric acid or 454.5 grms. of 70% acid, one should get 84 grms. of ammonia, going on the assumption that 97.7% of the acid was reduced.

Of course, this product is not obtained as fort ammonia, but probably the majority of it will be neutralized by the sulphuric acid which is present, thus forming ammonium sulphate and also ammonium nitrate. Therefoie, to recover the ammonia from these salts they must be treated with lime at a further expense.

As there are other cheaper methods of producing ammonium sulphate the author believes that this process is too expensive for technical working, as in the first case if a stronger acid than ½N or ¼N is used, the copper cathodes are going to be attacked, and this weak acid necessitates a larger plant, more cells, more men, etc., and in general, more expense, than if the concentrated acid could be reduced.

Figure 3 shows the general layout of the apparatus used in the attempt to synthesise ammonia by catalysis. It consists of anitrogen holder, an electrolytic hydrogen producer and an electric furnace.

The nitrogen which was obtained from ammonium sulphate and sodium nitrate as previously described was held in a gas holder and allowed to slowly bubble through a concentrated potash solution to

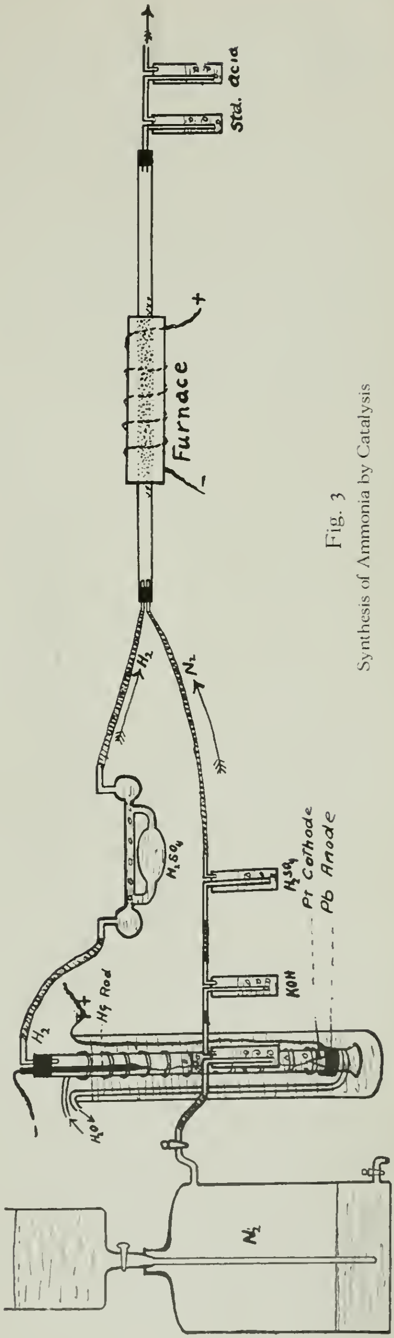


Fig. 3
Synthesis of Ammonia by Catalysis

remove nitrous fumes and any carbon dioxide, then through conc. sulphuric acid to completely dry it, before it was allowed to enter the tube containing the catalyser.

The hydrogen was obtained from the electrolysis of acidulated water. Figure 4 shows a diagram of this apparatus. It consists of a large glass cylinder which holds the acid, and a tube open at both ends suspended in the centre of this cylinder so that the bottom end of it is about one inch away from the bottom of the cylinder. A two-holed tightly fitting cork is placed in the upper end of this tube, through which run two glass tubes, one is for the exit of the hydrogen gas and the other tube dips about six inches into the acid in the tube. A platinum wire is sealed in the end of this tube and runs down to connect with the platinum cathode situated in the tube nearly at the bottom. The glass rod is then filled with mercury and thus contact results. The glass rod serves the purpose of keeping the platinum

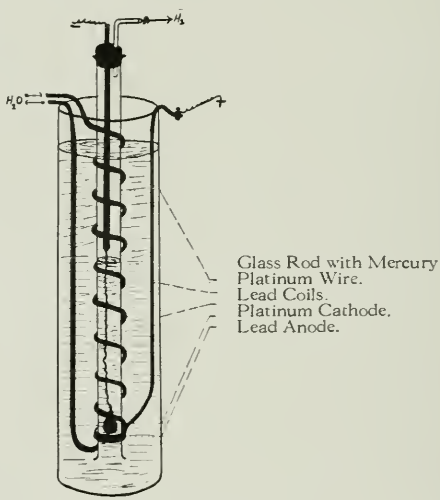


Fig. 4. Electrolytic Hydrogen Generator.

wire away from the sides of the tube and thus preventing the tube cracking if the wire should get hot due to too much current passing through it.

The anode consists of a lead strip dipping almost to the bottom of the cylinder, but so arranged as not to allow any oxygen to find its way into the central tube, and thus mingle with the hydrogen. The electrolyte was kept cool, by means of a lead coil placed in it, through which water was allowed to circulate.

The hydrogen was washed in a specially constructed wash-bottle containing concentrated sulphuric acid, by which means it was dried. This wash bottle, as may be seen in Fig. 1, overcomes the friction caused by the head of liquid in an ordinary wash-bottle, and thus delivers a continuous stream of hydrogen instead of a spasmodic one, as would be obtained by the use of an ordinary wash-bottle.

After the gases have been thoroughly dried, they enter the tube containing the catalyser supported on asbestos, in the proportion of approximately 1 vol. of nitrogen to 3 of hydrogen. The tube was heated by passing it through an electric furnace, the temperature of which was regulated by means of a rheostat.

The issuing gases were bubbled through standard acid, and any ammonia formed was determined by titration.

Experiments were carried on using different temperatures and catalysers, also by using dry and moist gases. The gases were made moist by allowing them to bubble through warm water instead of conc. sulphuric acid.

The following are the results which were obtained during a period of six hours.

Catalyst	temp.	gas.	gms. NH_3
Thorium oxide	500	dry	0
..	525	..	0
..	560	..	0
..	590	..	0
Uranium oxide	500	..	0
..	525	..	0
..	560	..	0
..	590	..	0
Tungsten oxide	500	..	0
..	525	..	0
..	560	..	0
..	590	..	0
Titanium dioxide	290	moist	0
..	375	..	0.272
..	500	..	0.391
..	500	dry	0.799
..	525	..	0.612
..	550	..	0.442

All the above experiments were carried on at the pressure of the atmosphere, and the uncombined gases escaping from the standard acid were not caught and sent back through the tube again, so the efficiency of the method was not calculated. However, I believe that if a pressure of some 150-200 atmos. were applied and that the experiments were carried on in a circulating apparatus somewhat similar to that of Haber's, that titanium dioxide would serve as an efficient a catalyst as osmium which he used.

The synthetic production of ammonia was also attempted by the production of chromium nitride. Chromium oxide was made from chromic sulphate, and the metallic chromium produced by a thermite reaction. The metallic chromium was then placed in a combustion tube and heated to red heat while a current of nitrogen was lead into this tube. No reaction between the metal and the gas could be effected however, as the tube would not stand the temperature.

It was the author's intention to produce chromium nitride, and then by an alternate stream of hydrogen and nitrogen, which was to be lead over it at a certain temperature, to obtain chromium hydride and then reform the nitride, thus giving a practically continuous stream of ammonia. This process seems to work very well with other nitrides.

Another scheme suggested itself, and that is to surround the cathode of an electrolytic cell with the chromium nitride, which is not attacked by dilute sulphuric acid, and any ammonia formed would be neutralized by the acid, thus producing ammonium sulphate which would be sold for fertilizer.

The production of ammonia by this process is only theoretical as whether chromium hydride or metallic chromium would be produced when the nitride was used up, the author does not know.

If this process worked it would have advantages over the other nitride method in so much as it would make the manufacturer independent, because a person cannot buy hydrogen without curiosity being aroused, whereas one may buy electricity without questions being asked.

In concluding, I may say that I do not think it will be very long before ammonia is synthesised on a commercial scale, as both nitrogen and hydrogen may be procured very cheaply. One cubic meter of hydrogen compressed to 150 atmos. may be purchased in Germany for about three cents, while the nitrogen may be obtained from the atmosphere.

E. F. Ball, '88, is Assistant Chief to the Engineer of Resurveys of the New York Central and Hudson River Lines.

F. C. Lewis, '08, is carrying on a general contracting business in Winnipeg, Man.

H. F. White, '03, is Assistant Superintendent of the George White & Sons Co., Limited, London, Ont.

M. H. Baker, '06, is the City Engineer of St. Thomas.

E. D. Monk, '08, is engaged with the General Electric Co. at Cincinnati, Ohio, as transformer specialist.

Wilfred C. Cale, '11, is in the employ of the Stone & Webster Engineering Corporation, Keokuk, Iowa.

H. V. Armstrong, '09, is superintending a water-works installation at Estevan, Sask., for Chipman & Power.

W. G. Collinson, '09, is at Durham, Ontario, as analytical chemist for the National Portland Cement Company.

Messrs. W. G. Worden, '11, B. H. Hughes, '14, M. G. Cameron, '09, and O. W. N. Charlton are recent additions to the Hydrographic Survey Department of the Interior. Their work lies in the vicinity of Lake of the Woods and west to the Red River.

L. S. Cockburn, '10, and E. L. Wenger, B.Sc., have become partners under the firm name of Wenger & Cockburn, consulting engineers, with headquarters in Regina.

W. M. MacAndrew, '11, is sales engineer with Allis-Chalmers-Bullock, Limited, in the Vancouver office.

SOME NOTES ON THE OAKVILLE VIADUCT AND THE DYNAMITING OF THE CONDEMNED ARCH RIBS, AUGUST 12th, 1912[1]

By C. H. Cunningham, B.A.Sc.

On Tuesday, August 13th, a rather interesting, and certainly unusual, event took place in Oakville when the big arch ribs forming the main span of the concrete viaduct under course of erection there, were dynamited. The arch span consisted of two ribs side by side, with vertical concrete posts carrying the slab and girders of the floor system.

These ribs had been completely concreted, but owing to several very serious faults in the construction, it was deemed advisable to destroy them and rebuild.

It was during the summer of 1911 that the county of Halton decided to call for tenders on a reinforced concrete viaduct over the 16-mile creek on the middle road between Oakville and the township of Trafalgar. Competitive designs in steel and reinforced concrete had already been prepared, calling for a clear roadway of eighteen feet. It was decided to adopt the concrete design and reduce the clear roadway to sixteen feet. Accordingly, these plans were prepared by Frank Barber, C.E., Toronto, as consulting engineer for Halton county, and on August 23rd, the contract was awarded. Two schemes were submitted, one of which called for the floor to be 40 feet above ordinary water level, and the other at 50 feet. Owing to the better grades obtainable on the approaches the latter plan was the one adopted.

The main features of the design are, a cantilevered slab floor supported on two main girders of various spans of 9 feet centres, which frame into square posts supported on heavy concrete piers, the stream itself to be spanned by a double rib arch of 135 feet 6 inches clean span on which the floor is carried by vertical posts and small girders. The arch ribs are of uniform width throughout, being 3 feet 3 inches square at the crown and increase in depth to 5 feet 6 inches at the skewbacks. The floor slab has an average thickness of 12 inches, and is reinforced entirely with ¾ inch round rods, cantilevering about four feet on each side.

The girder spans, which form the viaduct approaches on each side of the arch are eight in number, six being on the west side; and range in lengths from 34 feet to 48 feet.

The parapets are also of concrete, and have practically no ornamentation. In fact, the whole structure is noticeably plain. Immediately that the contract was awarded work was begun, in order to get as much done as possible before frost set in. Concreting actually commenced on the footings on October 5th, and by the end

1 In view of the recent controversy on the relative merits of steel and concrete, it would be well to remind the reader that faulty construction and insufficient safe-guarding of the concrete in freezing weather, were the factors which determined the engineers in condemming this work. The arches are being rebuilt on the original design which is considered in every way to be adequate. This article is not intended in any way to throw aspersions on concrete or concrete design. It simply aims to describe the method employed in blowing out the condemned ribs. It appeared elsewhere in a recent number of the *Canadian Engineer*.

of November the arches were ready to concrete. It was at this point that the regrettable trouble ensued which culminated in the contractor going ahead contrary to the engineer's orders and concreting the arch ribs on centering which was not sufficiently braced. An injunction and law suit followed, but meanwhile the arch ribs had been finished.

An investigation followed and showed up a considerable number of defects in the arches as erected. Also the weight of concrete was found to have been too great for the centring, which had shifted and thrown the centre line of the ribs out of a vertical plane to the extent of about three inches at places. Probably no one of the faults in itself would have been sufficient to condemn the arches, but when

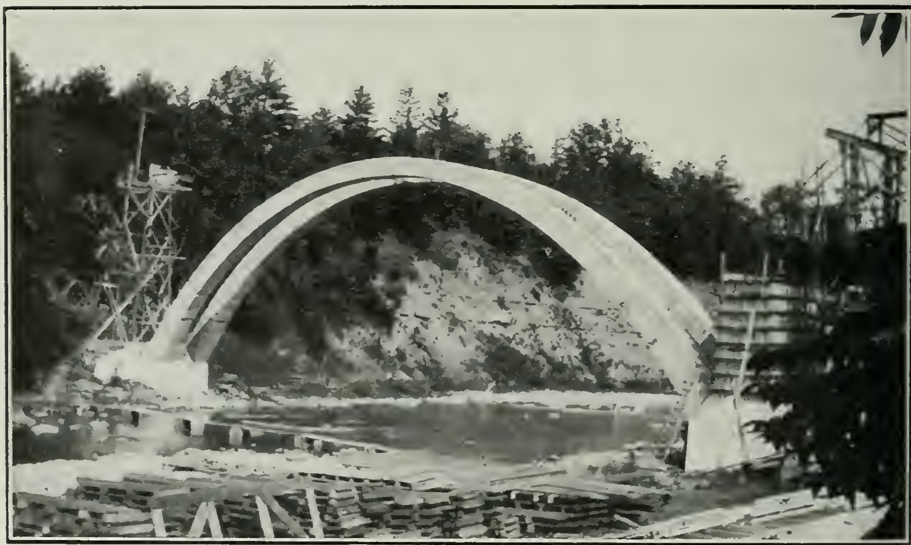


Fig. 1—Showing the Arch just before the blasts. (The notches where the rod were cut are plainly visible.)

all were summed up, the engineers did not feel that they could stand behind the structure as it was then, and recommended rebuilding then.

An adjustment was finally arranged and the original contract cancelled. Work was not resumed till the spring, when another contractor undertook to complete the job for the county on a cost plus 10 per cent. basis. Work recommenced the end of June, since when good progress has been made.

The council finally decided to blow out the old arches, and accordingly all preparations were made. The concrete outside of the reinforcing, which consisted of 16 bars ¾ inch diameter along the intrados and extrados, was chipped away and the rods themselves cut at two places near each end haunch. There was but one connect-

ing strut between the two ribs, situated at the crown. This was also severed and the ribs were blown out separately.

Charges were placed in the crowns and near each haunch.

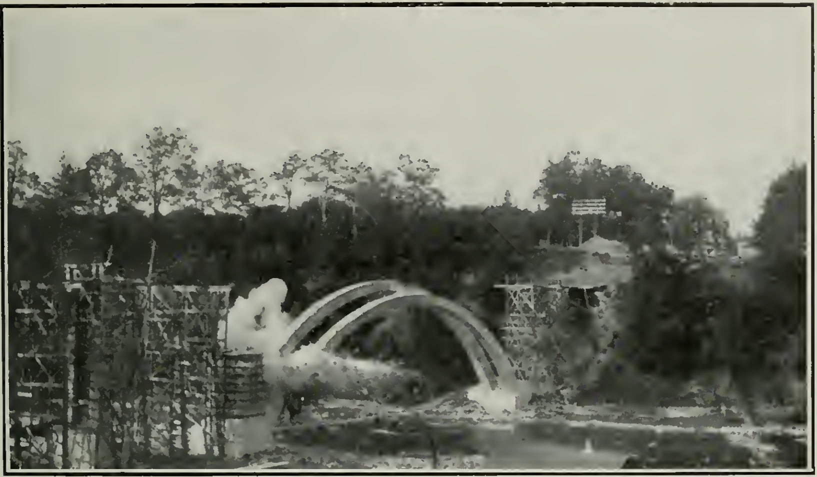


Fig. 2. The First Shot. Blowing the South Arch. (The charge in the last haunch did not explode, leaving a long end as seen in Fig. 3.)

Dynamite was used and fired by the electric spark to ensure simultaneous explosions, although any one charge would have sufficed to destroy the arch.

The south rib was dynamited first, after which the charges were

Fig. 3. The Arches blown out and lying in the stream. (Note the grillage of rods shown at the break.)

placed in the north rib. No mishap occurred whatever, and the skewbacks on the main piers were left unharmed. The photographs here reproduced will show the appearance of the arch before, during, and after the explosions. The reinforcing rods kept the concrete from breaking up to a considerable extent, and it will require a great deal of extra work to clear the stream bed in order to place the new centring.

The steel rods, wherever they were exposed by the splitting of the concrete, were noticeably clean and entirely free from rust. Although these rods were simple rounds having no corrugations or other means of creating a mechanical bond, evidences of a very considerable bond were very plain.

From a military standpoint it might be interesting to note the ease with which such a structure as this could be destroyed by dynamite if so desired. One heavy charge, favorably placed, would be sufficient to preclude the passage of a stream that was not in itself readily fordable. However, it should be remembered that it took over a week for two men to cut the rods, in order that there should be as little damage done as possible to the skewbacks and piers.

MATERIALS FOR ELECTRICAL INSULATION

By N. D. Seaton, B.A.Sc.

In the study of the subject of insulation, one is naturally led to ask, "Why does a thing insulate?" The answer might be given that it insulates because it is possessed of two distinct properties; first, the ability to stand the mechanical and electrical stresses due to the voltage used; and second, a conductivity such that but a negligibly small current can flow through it and break away. The first property is called the dielectric strength of the insulation, and the second, the ohmic resistance. The two together form its insulating power.

Electrical work is divided into two branches, wherein the requirements for insulation are widely different. In telephony and in telegraphy the voltages are low, so the dielectric strength is of relatively small importance: but the currents used are small, the circuits long, and an insulator of high ohmic resistance is required. On the other hand in apparatus designed for the generation and transmission of electrical energy, where the currents are large and voltages high, dielectric strength is the property mainly desired. This difference of requirements for an insulator gives to the term "insulation" a double meaning—to one branch meaning something having high ohmic resistance, and to the other, meaning something which has dielectric strength. The meanings are quite different since an insulator may have a high ohmic resistance and at the same time not resist high voltage breakdown. Air, which is about the poorest insulator in disruptive strength, has a very high ohmic resistance, while on the other hand insulating materials having the

best disruptive strength, such as mica, have a comparatively low ohmic resistance.

The above considerations, then, indicate the proper method of determining the fitness of insulation to withstand the conditions under which it must operate: that is, in testing samples we should actually subject them to electrostatic stress till they break down, and judge their quality by their dielectric strength and not by their ohmic resistance. The first cost of a machine for a given output depends largely on its rating, and that depends on the allowable temperature rise in the coils, and thus upon the temperature which the insulation of the coils will stand without deterioration. From this it follows that the quality of the insulation is of prime importance to users and manufacturers of electrical apparatus.

Conditions Influencing Tests on Insulation

In all insulation one of the greatest difficulties is to keep moisture from accumulating in it, it having an enormous deteriorating influence, and when a sample is to be tested, all the moisture should be removed. However, it does not do to dry samples of insulation too much, for this may lead to the sacrifice of their mechanical suppleness as well as a deterioration in their insulation resistance and dielectric strength. Moisture also has a depreciating effect upon the dielectric strength.

The insulation resistance decreases enormously as the temperature increases, not considering the effect of moisture. The influence of temperature on the dielectric strength is not nearly so much, and in fact, is scarcely appreciable as long as the material is not mechanically injured.

Every dielectric, whatever its thickness, requires a certain voltage to break it down, and this is proportional to the two-thirds power of its thickness.

In the case of insulation on a circular conductor, the volts per centimeter which the insulator will stand does not depend merely on the voltage and the thickness, but also on the curvature. A flat layer of insulator, say ¼ inch thick, will withstand a much greater voltage than the same thickness of layer bent around a small wire, and, therefore, having a greater curvature.

Ohmic Resistance Test

This test is usually made by placing the insulation across 550 volt direct current lines, in series with a moving coil voltmeter of known resistance. The machine tested must be set on insulating supports to prevent a short circuit occurring. The current which flows through the voltmeter, and hence the deflection of the voltmeter, depends on the insulation resistance which is found as follows:

Let a = voltmeter resistance.
Let b = insulation resistance.
Let d = reading of voltmeter in series with insulation with 500 volts across them.

Then the current = 500 ÷ (a + b); but the current also = d ÷ a. Hence 500 ÷ (a + b) = d ÷ a,

and ∴ $b = a\left(\frac{500 - d}{d}\right) = a\left(\frac{500}{d} - 1\right)$.

The principal use of the ohmic resistance measurements of insulation lies in the comparison they afford of the damp-proof qualities of various dielectrics, and in the measure of the degree of dryness obtained. This is quite important, because the presence of moisture in almost all the forms of insulation, is a source of great trouble.

Tests for Dielectric Strength

Among the tests which are regularly made to determine the quality of the insulation of a piece of electrical apparatus, is that known as the disruptive or dielectric test.

The following is a discussion of the design, selection and use of apparatus for making such a test. In considering the apparatus, a number of points must be considered.

Maximum Testing Voltage

The maximum testing voltage required depends on the nature of the material or apparatus to be tested. For lower voltage apparatus the testing voltage is usually several times the rated voltage of the apparatus, while for higher voltages, the testing voltage is rarely more than double the normal rated voltage. In the case of materials almost any range may be required from a few hundred volts up to 100,000 or 150,000 volts, so that a well-equipped testing laboratory should be capable of giving this range of voltage. The following table gives a list of the maximum testing voltages suitable for various classes of work, together with the capacity in kilowatts which will be found sufficient for most work for each.

Maximum Testing Voltage	Capacity (kilowatts)	Maximum Testing Voltage	Capacity (Kilowatts)
2,000	1	50,000	50
6,000	3	100,000	100
10,000	5	150,000	150
30,000	30	250,000	250

Frequency of the Testing Circuit

The frequency of the circuit on which the testing transformer is used, determines, in some measure, its size for a given output—the lower the frequency the larger the size. A more important consideration governing the output follows from the fact that the amount of charging current varies directly as the frequency of the testing circuit. So that the higher the frequency the larger must be the testing transformer. Furthermore, the dielectric loss in insulation, at a stress approaching the disruptive strength, also, varies approximately as the frequency, requiring additional testing capacity.

Static Capacity of Apparatus to be Tested

Small samples of insulation require but a very small output in the testing transformer, but with large machinery or with cables, a much larger output is required on account of the current necessary to charge the apparatus considered as a condenser.

Variation of the Testing Voltage

There are three principal methods of varying the testing voltage when making dielectric tests.

(a) By varying the generator field.

(b) By means of a resistance in series with either the primary or secondary of the testing transformer.

(c) Variation by steps.

In the latter method a great range of voltage may be had by bringing out loops from the high tension side of the testing transformer with further combinations of the low-tension windings. Very close regulation of the testing voltage may be obtained by the use of a second transformer. It is connected directly to the line and has a large number of loops in its secondary winding, which are connected through suitable dials to the primary of the testing transformer.

Measurement of the Testing Voltage

(a) By ratio—in the lower voltage work where the static capacity of the apparatus is small the simplest method is to measure the primary voltage and multiply by the ratio of transformation.

(b) By voltmeter reading in the high-tension circuit—a direct reading voltmeter of the current operated type used in series with non-inductive resistance, is used in this method.

(c) By spark-gap in the high tension circuit—this method has been recommended by a committee of the A.I.E.E., with a spark-gap to consist of needles, the distances for the various voltages being given.

(d) By voltmeter and a step-down transformer.

Provision for Locating Faults

In many tests it is desirable to locate the faults which occur during the test. One of the most satisfactory methods is to hold the testing current a sufficient length of time to produce burning of the insulation at the point of fault. For this purpose a resistance or inductance in some part of the circuit is very satisfactory.

Rating of Testing Transformers

The usual method of rating transformers is based on the temperature rise when the transformer is carrying the rated load continuously. As a testing transformer is rarely, if ever, used continuously, it may be rated on the maximum current that the transformer can deliver for short periods of time.

Testing Methods

In the testing of materials, the greatest variety of materials will be met with—as fabrics, porcelain, oil, papers, and almost every conceivable combination of materials.

For sheet material, metal terminals with edges well rounded should be used. For irregular shaped solids, the conditions of service should be simulated as nearly as possible. The method of applying the voltage is not of much importance, whether by steps, by graded rise, or by the application of full voltage at once, where the test is a predetermined amount, and the testing voltage is not high, say not over 25,000 volts.

As the actual breakdown point is desired in most tests on material, the voltage must be applied in pre-determined steps, or the rate of increase must be such that readings may be taken and the exact point of breakdown determined. The voltage may be read by ratio or by a static voltmeter in the high tension circuit.

In the testing of dynamos, motors, transformers, cables, etc., their static capacity must be considered, requiring larger testing apparatus and greater care in the application of testing voltage.

Materials Used for Insulation

Up to the present time the engineer has had to choose his own insulating material from the ones afforded him by the trade. But the materials at hand are not all that could be desired, especially in high tension work, which is greatly handicapped by the lack of suitable insulating materials. Some materials may have one good property in a very marked degree, but at the same time may lack in one or more of the other essentials.

The following is a general idea of the desirable and undesirable qualities of insulating materials, and an indication of some points where improvements might be useful.

(1) Electrical properties.

- a.—Insulation resistance or conductivity expressed in ohms per centimeter.
- b.—Disruptive or dielectric strength, measured by the potential necessary to puncture the material.
- c.—Dielectric constant, or specific inductive capacity in microfarads, or a condenser having a particular material as dielectric separating the metal plates. This last named property is less important than the two preceding.

(2) Mechanical properties.

- a.—Strength and workability, in case of solids.
- b.—Flexibility and workability in case of semi-solids.
- c.—Viscosity, in case of liquids.

(3) Chemical Properties.

- a.—Combustibility.
- b.—Property of resisting the influence of moisture, air, oil, acids, etc.

The factors which may considerably influence the properties of insulating materials during use are the following:

1.—Rise of Temperature. It may be due to (a) current passing with not enough chance to radiate the heat generated: (b) Heat conducted into the insulation from outside sources, such as the metallic conductor: (c) Dielectric hysteresis, due to very frequent application and withdrawal of high electric stress, such as high voltage alternating current, with not enough chance to radiate the heat generated.

2.—Mechanical stress resulting in change of shape or breaking.

3.—Chemical action, as of water, oil, ozone, nitrous fumes (which may be generated by brush discharges) or gases and fumes developed by factory processes in the neighborhood of electrical apparatus.

Desirable qualities are mainly, good insulation resistance, high disruptive strength, and fair mechanical properties, especially workability. Undesirable qualities are, combustibility and changes in electrical and mechanical properties with rise of temperature, or with age, and of course, high price.

To make a chemical classification of insulating materials it is practical to consider them under the heads of:—1. Organic materials, liquids and solids: 2. mixtures of organic and inorganic materials: 3. inorganic materials.

1. (a) Liquid organic materials. These comprise the materials used for transformer insulating and cooling, for condensers and for circuit breakers. Such liquid insulators are the liquid organic compounds.

(b) Organic compounds used as solids of more or less plastic state: These are represented by varnishes, lacquers, drying oils, rubber, and compounds made from the different cellulose materials, such as textile materials, wood, etc. Some of the disadvantages of these as used nowadays are, loss of mechanical strength, insulating power and dielectric strength by age, by high temperature or by high electric stress. All of them are more or less inflammable and some of them, such as gutta percha, are quite expensive.

2. Mixtures of organic and inorganic materials. Typical representatives of this group are materials made of asbestos, or of mica with varnish, rubber or paper. The asbestos compounds, as a rule, lack high insulating power and also mechanical strength. The mica papers lack flexibility and are not apt to be uniform throughout.

3.—Inorganic materials. These are represented by slate, marble, asbestos, porcelain, and glass. They are practically unaffected by heat but lack entirely flexibility and are usually expensive, especially when manufactured into desired shapes.

A comparatively perfect insulation would have the flexibility of rubber and the ideally high insulating and dielectric strength of mica, and should, of course, be cheaper.

Perhaps it would be suitable here to give brief descriptions of some of the more important insulating materials.

Rubber

Para rubber is the name applied to rubber coming from widely different localities, the principal of which are: Brazil, Bolivia and Peru. However, it is not the locality which causes the difference in the paras so much as the methods of gathering and of coagulation. They might be conveniently divided into three grades:—

Fine—The clean and thoroughly cured rubber.

Medium.—In the centre of which there is more or less moisture due to imperfect curing.

Coarse.—The residue scraped from the collecting vessels.

Owing to the ever increasing demand for rubber, the price of para has advanced, and as the supply was inadequate to the demand, the use of rubber other than para became absolutely necessary. Various grades are found in different parts of the tropical world, Africa being the chief source of the better qualities. At first the methods of curing were very crude, but these defects have been largely overcome, so that to-day rubber compounds can be made containing no para, which in almost every respect, will give as good results as the more expensive article.

The most important properties of rubber, considered from the standpoint of insulation, may be grouped under the following heads:

1.—Non-hygroscopic.

2.—Dielectric.

3.—Mechanical strength.

4.—Elasticity.

The last three of these properties are materially affected by the process of manufacture, and each one is developed more or less at the expense of the others.

In selecting a rubber compound the manufacturer of insulation carefully considers the following points: First, conditions of service; second, what quality will best meet the conditions with an ample factor of safety and the least cost to the purchasers; third, how in the process of manufacture the most essential qualities of the rubber may be developed so that the resulting compound may be the best possible.

The purchaser of a rubber compound quite naturally submits it to some test which he considers adequate to show in what measure it will meet his requirements. Let us now consider some of these tests.

1.—Acetone Test. In all rubbers there is always a certain amount of oily or resinous matter soluble in heated acetone. Unvulcanized fine para rubber contains from one to two per cent. of this extractive matter, but it has been found that a good compound may contain as much as eight per cent provided it is properly vulcanized.

2.—Ash Test. This is simply the burning up of organic matter in a compound, leaving as ash the inorganic or mineral matter. The amount of rubber in a compound varies considerably: it is seldom less than 30 per cent nor more than 40. The percentage

of ash required must cover such variations. A minimum of approximately 56% and a maximum of 68% would accomplish this.

3.—Stretch Test. Elasticity is the most obvious property of crude rubber, and on this account it has been assumed that good rubber compounds are elastic and that poor ones are not.

Any rubber compound, good or bad, is, at one stage of manufacture, a plastic mass about like putty. Strength and elasticity are given this mass by vulcanization. Precisely the same compound can, by changes in the quantity of sulphur and method of vulcanization, be made highly elastic or as brittle as glass. It has been found that as an insulator the brittle compound is the better from an electrical standpoint, but of course, is useless as a covering for wires and cables. It is obvious, therefore, that the most efficient rubber insulation is that possessing the greatest dielectric and mechanical strength consistent with the retention of sufficient elasticity.

There are good reasons why the Stretch Test should never be applied to insulation on large conductors, or to thick insulation for high pressures, irrespective of the size of the conductor. The mass to be vulcanized on large conductors cannot be done without the sacrifice of elasticity sufficient to make the ordinary stretch test almost impossible. When the outer surface of a thickly insulated conductor has been vulcanized to a point where the elasticity is greatest, the inner layers are under-vulcanized and are therefore highly perishable.

On the smaller sizes and for walls up to one-eighth of an inch thick a stretch test should be useful. The manner of performing it is as follows: a four inch sample is cut from the conductor and marks two inches apart are placed on it, the sample is then stretched until the marks are six inches apart, and on being allowed to return they should be at least two and one-half inches apart. For larger sizes and heavy walls, a sample cut from the conductor the full thickness of the insulation is bent double and the process repeated in reverse. The sample should show no signs of cracking.

4. Insulation Resistance Test. The National Board of Fire Underwriters requires, for a No. 14 B. & S. with 3-64 inch wall of rubber insulation, 200 megohms after 60 hours immersion at 60°F. Telephone companies for the same size and wall of insulation require 500 megs. after 24 hours immersion at 60°F. With the latter as a basis, the insulation resistance for any size of conductor and wall of rubber can be obtained by the use of the formula

$$\text{Constant} = \frac{\text{resistance}}{\log_e (D \div d)}$$

5.—Voltage Test. This is the most important test in determining the practical efficiency of insulation. Excessive voltages should be avoided as they strain the insulation, thereby weakening it and shortening its life. A test of 2½ times the maximum working emf. for 5 minutes after 24 hours immersion, or for twice the maximum working emf. for 30 minutes, will not strain the insulation, but will develop any structural faults and establish the existence of a factor of safety. When the voltage is nominal and the walls of insulation

comparatively thick the working emf. as above would evidently be inadequate. In this case the engineer should determine the maximum emf. which he would be willing to use in the conductor in question, and base the voltage test on this. For example: No. 14 wire with 5-64 inch walls of rubber could safely be used for 2,000 volts of alternating emf., though the actual working stress might be nearly nominal. The test with 2½ as a factor would be 5,000 volts for 5 minutes.

This rule may not be scientifically exact, but it is simple and no insulation successfully tested under it could have either structural faults or inherent weaknesses sufficient to endanger its successful operation. The object of the voltage test should not be to determine the greatest stress to which the insulation can be subjected, but to establish the existence of a safety factor.

Mica

Mica is an anyhdrous silicate of aluminium and potassium or sodium. The most transparent qualities are composed of the above mentioned substances, but the less transparent qualities contain magnesia, iron or earthy matter. It crystallizes in layers and may be subdivided down to a thickness of 0.006 mm.

It can safely be said that no satisfactory substitute has been found for mica in commutator construction. The commutator is the hottest part of the machine, and mica will not carbonize.

There are two kinds of mica, amber and white. The amber mica is used between segments, since it can be turned on a lathe better than white. White mica is harder than amber, but much more flexible, and splits into comparatively large sheets which makes it quite applicable to repair work. All variations from white, especially greenish or bluish tinge, are harder and more brittle.

The ultimate disruptive strength of a selected quality of amber mica, taken from a number of samples up to 5 mils in thickness, varied from 1,980 volts per mil to 4,300 volts. The average failing is at about 2,500 volts. The averages of two assortments of poorer grade, mottled samples were 2,200 and 2,400 volts per mil, respectively. White mica, both large and small sheets, averaged 3,100 volts per mil.

The successful building up of thin overlapping sheets and the moulding of finely divided mica into plastic forms, has simplified the insulation of many machine parts. These insulations, known by several trade names, share to a great extent the value of mica. Built-up mica, if cemented with a non-hygroscopic varnish, possesses a disruptive strength practically proportional to its thickness. Backed with a tough paper or cloth, for mechanical strength, it has advantages over pressboard and other fibrous insulations for slot or coil work. The following are a few characteristic built-up mica insulations.

Micanite. In this product the mica is split up into layers and these thin sheets are stuck together by an insulating cement. Natural mica cannot be bent except in a very thin sheet, but micanite,

when heated, may be bent into any suitable form. If the thin sheets are allowed to overlap and a non-hygroscopic cement is used, micanite makes an exceedingly good insulator. It is made in the form of plates, which may be moulded, and also as cloth and paper.

Megohmit. This is similar to micanite. The plates consist of thin mica sheets stuck together with shellac in the case of hard plates, and with a mixture of vegetable adhesive materials, in the case of flexible plates. The megohmit paper consists of flexible plates having a covering of Japanese paper, and megohmit linen is similar except with a covering of linen instead of paper. The hard plates become soft at about 80°C., but on cooling regain their original mechanical strength. Channel plates and troughs may be made from megohmit plates.

Sheet Insulations

Paper and other fibrous materials are, owing to their close homogeneous texture and even qualities, used to a great extent as insulation. Manilla, express and bond papers probably head the list as far as good disruptive and mechanical strengths are concerned, although the so-called red rope paper is probably most extensively used. These four, when coated with good insulating varnish make excellent dielectrics.

No paper of any kind should be used without first being coated with some moisture proof varnish, because all untreated papers are more or less hygroscopic. Indeed, the present tendency is to abandon reliance upon the insulating properties of these fibrous materials and to depend rather on the films of varnish with which they are coated or impregnated.

One of the most widely used insulations is flexible pressboard. The best quality is made of leather findings and comes in yellow and red. For thicker insulating sheets, preparations of vulcanized or hard fibre are available, including such materials as bone fibre, kartavert, amyloiden, leatheroid.

Hard rubber compounds are sometimes used for sheet insulation, especially those vulcanized with asbestos fibre, but flexibility is, of course, impossible.

Fabrics

At the present time, insulations made of cloths and fabrics are almost indispensable These serve as a framework to hold the film of insulating varnish, so that their selection is quite important. Cambric, muslin, lonsdale, and batiste are the trade names of the best materials for this purpose. Those materials which have the smoothest surface and are free from nap and fuzz are to be recommended, and for good results the cloth should be first ironed or singed to obtain as smooth a surface as possible; otherwise the nap or fuzz projecting through the film of varnish breaks up the continuity and results in a variable disruptive strength.

There are several different methods of treating cloth with

insulating varnishes. Some require little more than a paint brush and a can of varnish. The cloth is laid on a bench and painted over until the required result is obtained. Another and superior method consists in passing the roll of cloth through a trough containing linseed oil, the cloth having been first dried in an oven. It is again dried and drawn through a vat of varnish which is placed at the bottom of a chimney-like oven. After going through the varnish the roll slowly ascends through the oven and then descends again. The operation being repeated until the coating is sufficient.

Considering the insulations on wires, the materials most commonly used are, cotton, silk, asbestos, and enamel. Cotton must be reinforced with compounds or varnishes to give satisfactory results, and may be used for temperatures below 100°C. Silk is better than cotton in that it takes less space and is only used where a very thin insulation is imperative, owing to its cost.

Although enamel does not come under the head of fabrics, yet it is used to a considerable extent in place of them, so that its discussion is not altogether out of place here.

Enamelled wire is coming into use more and more, and will probably supersede cotton, silk and asbestos. It has a high insulation resistance, is non-hygroscopic, and will withstand a higher temperature than cotton or silk and takes up less room than either. With enamelled wire it is often possible to give a machine a higher rating or to allow for greater overloads, and thus effect a considerable saving in the construction. The danger in enamelled wire lies in its tendency to crack and when bent around small turns, and it also is liable to become brittle.

Oils

It was not until 1859 that oil was used as an insulator, and then it was in connection with submarine cables. As long distance high voltage transmission came to be used, oil insulation was found to be absolutely necessary. Previous to 1890 there had been a limited use of oil for insulating transformers and induction coils, but this was confined to a few of the small sizes and low voltages in transformer work. In 1891 transformers were used, wound for 30,000 volts and having oil as an insulator.

Mineral oil is used universally for this purpose because of its cheapness and general efficiency, and the apparatus is almost always immersed in it. Besides serving as an insulator, oil forms a cooling medium whose function is to receive the heat from the apparatus where it is generated and carry it away. Owing to the fact that oil expands when heated, the hot oil rises and the colder oil from the sides of the containing tank flows in to take its place, thus setting up a circulation of the oil which continually cools the apparatus.

Almost all oils—mineral, vegetable and animal—when pure, are very good insulators. There is a wide difference between the insulating qualities of various mineral oils, but this difference seems to be more an index to the purity of the oil than an inherent difference due to variations in the chemical composition of the oil itself.

By purity is meant freedom from water, alkali, acid or foreign matter of any kind.

Most properties of oils as now used are desirable, but one bad feature inherent in them is their combustibility. In the case of circuit breakers as well as of transformers, where accidental high potential may have arced through the oil, the broken down insulation should soon repair itself and the oil should soon come back to its original insulating power. Besides this, oils should be considered as to their effect on the different materials they come in contact with. For instance, fatty acids are undesirable because they are apt to react with copper. Then, too, the products resulting when the discharge goes through, should not be such as to injure any part of the apparatus.

Methods of Testing Oil Insulation

(a) The method usually employed in determining the insulating value of an oil is to test its dielectric strength. Satisfactory insulation resistance tests are difficult to make and, while showing something of the quality of the oil, are not of as much value as dielectric tests.

The usual method is to immerse spark gaps in the oil, the gap being set at a known distance, and gradually rising the potential until rupture occurs.

(b) Another important test is the "flash and fire" test. By flash test is meant the temperature to which oil must be heated in order to give off gases which burn when ignited and which form explosive mixtures with the air. By fire test is meant the temperature to which oil must be heated so that the oil itself will take fire, and continue burning when a flame is applied to its surface. The general method is to heat the oil gradually, applying a test flame at intervals, and noting the temperature at which a slight flash occurs, and also the temperature at which the gases take fire and continue burning.

(c) Moisture. The deteriorating effect of moisture on the insulating value of an oil is very marked. As there are many ways in which mositure may enter the oil, tests for moisture become very important.

The test consists in placing a small amount of oil in a cup, into which is plunged a piece of iron or other metal, at a temperature just below a dull red heat. Any hissing or crackling noise indicates the presence of moisture.

Specifications

The following is a brief specification for insulating oil:

(1) The oil should be a pure mineral oil obtained by fractional distillation of petroleum unmixed with any other substance and without subsequent chemical treatment.

(2) The flash test of the oil should not be less than 180°C., and the burning test not less than 200°C.

(3) The oil must not contain moisture, alkali, or sulphur compounds.

(4) It should not show an evaporation of more than 0.2% when heated at 100°C. for 8 hours.

(5) It is desirable that it should be as fluid as possible, and that the color be as light as can be obtained in an untreated oil.

Insulating Varnishes and Paints

Insulating varnishes are employed to improve the initial insulating properties of papers, fabrics, and fibrous materials, which are impregnated with them, and to maintain the constancy of their initial insulation resistance.

An insulating varnish should give a permanent uniform coating of insulation which will not become brittle, crack, or peel off. It should be plastic and should not flow below 200°C. It should not cause corrosion and neither water, acids nor oils should affect it, and it should be cheap.

(Varnished cloth and paper are now used universally, but the day of the simple gum varnish is past. It has been found that insulation dipped in a hot bath of copal gum or shellac would "check" when chilled and tend to crumble away under vibration. Moisture soon finds its way into the minute cracks, and destroys the insulating value. These gum varnishes must also be dissolved in alcohol, naphtha, or some highly volatile liquid, and the result is that there is danger of fire, as well as waste owing to evaporation. Asphalt, bitumen and other mineral patches have faults similar to gum varnishes. Linseed oil, when thoroughly boiled out, has been combined in many successful varnishes, but after the lapse of time it has a tendency to oxidize and crack).

The following are a few of the better class of these varnishes:

(1) Sterling Insulating Varnishes.

These are composed mainly of linseed oil, turpentine and resin. They have a high uniform insulation strength and are claimed to be impervious to the action of water and oil. They are generally applied to fabrics of paper, which are given a thin coat and afterwards baked in an oven at from 60° to 80°C.

Other Sterling products are:—Sterling Quick-Drying Insulating Varnish; Elastic Insulating Varnish; Black Plastic Insulation.

(2) Armalac.

A fault sometimes found with linseed oil varnishes is that the acid in the oil corrodes the copper of the windings. Another fault is that lubricating oil acts on the linseed oil and upon insulations impregnated with these varnishes.

Another class of varnish has been brought out which overcomes these faults. A typical one of this class is Armalac, which is composed of black paraffin wax dissolved in petroleum naphtha, the melting point of the paraffin being permanently raised by a secret process. It is claimed that although its melting point is about 300°C., it never becomes hard or brittle, that there is an entire absence of resin acids and that it does not affect copper.

No varnish is suitable for all purposes. A varnish which corrodes may be used, provided another varnish which does not do so is applied next to that copper. A varnish which remains soft and pliable is best for form wound armature coils, as flexibility is essential in assembling and repairing them. In some cases a varnish need not have high insulating properties, if only it is tough and durable. For some purposes a varnish must dry quickly in air and have a hard smooth surface. In some cases a waterproof varnish is necessary, and again it may have to resist acid fumes or heat.

(3) Benolite.

A new varnish has come out under the name of Benolite. It is a black, waterproof, oil-proof, flexible varnish, which can be dried in air in from four to six hours, the drying being caused by chemical action other than by oxidation, and stopping at a point which leaves the varnish quite flexible. Once dry, Benolite is absolutely acid and alkali-proof, the finish not only being unaffected itself, but protecting the copper or cloth underneath from corrosive action.

A single layer of cotton tape painted with Benolite is stated to have a dielectric strength of from 6 to 10 thousand volts. A superior insulation can be obtained by taping the article with cotton or linen tape, painting four or five times the Benolite and drying each coat for about two hours. The Benolite thoroughly penetrates the tape and forms a fine glossy surface. The result is a thoroughly dry homogenous mass of insulation having a high dielectric strength. The fact that it drys by chemical action makes it unnecessary to be in contact with the air to dry, and its penetrating and flexible qualities make it an excellent material for this kind of work.

Special Insulations

Some of these have already been referred to, but there are a number which do not come under any of the foregoing heads.

(1) Asbestos Insulation.

Of late years there has been a tendency to use fireproof insulation on cars, and it is becoming more general on account of the recommendations of the Board of Underwriters, which require under-frames to be covered with a fire-proof insulating material.

Two new materials have lately been brought out, called asbestos building lumber and magnesia building lumber. The former is composed of asbestos fibre, each fibre being coated with a cement, and these coated fibres then united by a peculiar process giving a substance of fibre-like construction, which under great pressure can be moulded to any shape. The other material is made up of the natural fibres of magnesium silicate cemented together by the use of an artificial magnesium silicate, which is crystallized around them. It may be moulded also, and both materials may be cut and sawn, and in fact used in a similar way to ordinary wood.

Tests for insulation resistance were made at 550 volts, showing the following results:—

ASBESTOS LUMBER

Thickness	Resistance per inch of Thickness
1-8 inch.......	0.97 to 2.3 megohms
¼ inch........	0.2 to 1.2 megohms
½ inch........	0.8 to 1.5 megohms

MAGNESIA LUMBER

Thickness	Resistance per inch of Thickness
1-8 inch.......	1.3 to 8.7 megohms
¼ inch........	1.05 to 4.1 megohms
½ inch........	1.09 to 3.5 megohms

The break-down voltage test was made upon specimens of both materials, dried five hours at 150°C., and also upon undried specimens. In the Asbestos Lumber the results showed breakdown voltages of from 7,000 to 21,000 volts per inch of thickness, while when undried they were from 2,700 to 12,000 volts per inch of thickness. In dried magnesia lumber the break-down voltages varied from 9,000 to 30,000 volts per inch of thickness and in undried material it was from 4,800 to 15,000 volts per inch of thickness.

The absorption tests tended to indicate that both materials absorb a certain amount of moisture, the magnesia lumber showing the greater tendency in this direction.

As a result of tests for strength, it was concluded that of the two, asbestos lumber possessed better mechanical properties than magnesia although the latter is a better electrical insulator.

One of the chief uses to which the material is being put is for insulating and fire-proofing the lower parts of cars, the lumber being painted with moisture proof paint.

(2) Bakelite.

The Bakelite Co. is the manufacturer of a product possessing valuable characteristics for insulating purposes, called "Bakelite." It possesses some of the combined properties of amber, hard rubber and celluloid, but it is harder and stronger than any of them, withstands heat and is not attacked by any solvents nor by most chemicals. The substance is totally insoluble and infusible, and does not soften even at a temperature of 572°F. It may be obtained either transparent or opaque, and can be compounded with various filling materials, such as asbestos, clay, wood pulp, minerals, etc., and shaped or moulded to articles of unusual strength. It can be sawed, polished, and turned, and when used to impregnate wood and other porous bodies, renders them harder and more resisting to chemical and physical influences. The material does not emanate sulphur, like hard rubber, nor nitrous products like celluloid, and if heated it does not catch fire nor melt, but simply chars and then burns with difficulty. The various forms of "Bakelite" are applicable to such a variety of purposes that it is necessary to specify what use is intended in order to obtain the proper variety.

(3) Insulation by Freezing.

A rather unusual line of investigation has been taken up by Mr. Tesla, namely, that of insulation by freezing. Long ago Faraday estimated that water and aqueous solutions insulate a hundred times better if frozen solid. Tesla has confirmed this, and in the course of his experiments has ascertained the following points: (1) Under certain conditions, where the leakage of the electric charge

ordinarily taking place is rigorously prevented, ice proves itself to be a much better insulator than has heretofore appeared. (2) That there is benefit in adding other bodies to the water. (3) That the dielectric strength of ice increases with the reduction of temperature. (4) That there is most gain in regard to alternating currents at high rates, very thin slices of ice being capable of enduring electromotive forces even into thousands of volts. Upon this and other data he has made some ingenious applications, as shown in his patents.

In carrying out his methods he uses a hollow conductor and passes the cooling agent through it or he uses expressly for the circulation of the cooling agent an independent channel, and freezes the adjacent substance in which the conductors lie. Another plan illustrates a method of immersing the primary and secondary of transformers in a freezing jar.

(4) Electrose.

About eighteen years ago there was developed and placed on the market a form of insulating composition possessing many unusual characteristics. Although the material was non-fireproof, yet it was found to be well adapted to high voltage work, and capable of withstanding arcing without destruction. Beginning in 1902, the material was used for high tension line insulators on the circuits of the Niagara Falls Power Company and the Canadian Niagara Power Company. It is claimed that, although lightning has frequently caused arcs to form around the insulators, not one has been damaged by it. This result is attributed to inherent flexibility of the material, which permits it to withstand heat expansion strains which would immediately rupture either glass or porcelain.

The material which is called "Electrose," possesses hardness, and toughness without brittleness, great strength, a smooth polished surface, and is moisture, water and oil proof. It will not shrink, warp or change its form under ordinary conditions, and is suitable for use in temperatures below 200°F.

The following tests illustrate some of its characteristics: a sheet 12 inches by one-eighth inch arced around at 75,000 volts but did not puncture: a similar sheet ¼ inch thick withstood 80,000 volts without puncturing: a corrugated rod type insulator 7 inches long by 15 inches in diameter arced over from terminal to terminal at 80,000 volts, but did not puncture.

Energy Losses in Insulation

In experiments to test the dielectric strength of insulating materials by means of alternating emf., it is a noticeable fact that heat is always developed in these materials. When the amount of material involved is large, ordinary instruments will show an actual loss of energy.

The materials used in the test were of a fibrous nature, such as paper or cloth, both treated and untreated, and a great many tests had to be made in order to arrive at reliable results. Tests were also made on finished apparatus. Alternating current at the

standard frequencies of 25, 60 and 125 cycles was used, with emf. varying from a few thousand volts up to 100,000 volts. The results, while true for all potential stresses, are of little importance in ordinary low potential apparatus, but become of great importance in very high potential working. The results have also a direct bearing on questions of long continued tests of dielectric strength of finished apparatus at very high voltages.

The loss above mentioned has been found to depend on (1) temperature, and (2) frequency, and temperature changes with the voltage.

Variation of Temperature Due to Variation of Stress

The following are the results of a series of tests on insulating materials:

(1) With moderate stress the temperature rises at first rapidly, then more slowly, then becomes constant.

(2) As the stress is increased, a point is reached where the heat is developed faster than it can be carried away and the temperature rises until the material chars and breaks down.

(3) When material is not well dried, the temperature rise much more rapidly than in well dried stock.

(4) The final break-down in fibrous materials usually results from the burning of material and not from mechanical rupture.

(5) It follows from (4) that if the temperature is kept low, the stress required to cause break-down will be much greater than if the material is not so cooled.

(6) With a given stress, the initial and surrounding temperature has much to do with the rise. The higher the initial temperature, the greater the rise.

Variation of Loss Due to Variation of Temperature

The following points were brought out in experiments to ascertain the loss due to variation of temperature.

(1) The energy loss in fibrous materials increased with temperature.

(2) The ratio of increase in the loss depends on the kind of material and its condition.

(3) The local heating found in a mass of poorly ventilated material is due to a greater initial loss in one portion causing increased heating, this in turn causing greater loss, etc., until the material breaks down.

(4) The rate of increase of loss is greater at high than at low temperatures.

(5) A long continued test at high stress may seriously injure the insulation of a piece of apparatus, without this being made apparent by the test.

Variation of Loss Due to Variation of Voltage

The results of a great many experiments show the following, with constant temperatures:

(1) The increase in loss is usually slightly greater than the square of the emf.

(2) With varying temperature the loss will increase more rapidly than the square of the voltage.

(3) The rate of increase will depend on the facility with which the material can get rid of its heat.

(4) It will also depend on the initial temperature.

Energy Loss in the Insulation of Large Alternators

From tests made on two 5,000 k.w. alternators, at approximately 5,000, 10,000, 15,000 and 20,000 volts, the following conclusions were arrived at:

(1) The variation in loss due to change of stress is slightly greater than the square of the applied stress.

(2) There was a great increase in the loss for the higher temperature.

(3) The loss at 25,000 volts is not sufficient to cause any injurious heating.

(4) The rate of increase of loss shows that above 25,000 volts the loss would be sufficient to cause heating and damage to the insulation, if the stress were applied for any considerable time.

Selection of Machine Insulation

Materials intended for the insulation of electric machinery should pass three classes of requirements involving tests to withstand (1) Current Leakage, (2) Lightning Discharge, (3) Heat.

Number 1 includes not only actual insulation resistance tests under any set of conditions measured in megohms, but also hygroscopic tests which affect the insulation resistance of many porous materials. Number 2 includes the determination of the resistance due to disruptive discharge from any cause, whether accidental metallic contact with a high-tension line wire, proximity to high frequency wireless station apparatus or static discharge during a thunderstorm. Under number 3 is included tests covering the effects due to the presence or absence of heat, such as the mechanical failure of materials with extremes of temperature or with rapid alternation of heat and cold.

No station leading from an overhead line can be absolutely protected from lightning discharge, and it frequently happens that the high-potential strain from this cause reaches the insulation of machines. Disruptive discharge of any kind acts like a fluid in motion with erratic splashings which have been called side flashes. These uncontrolled discharges have been found to strain and break down the insulation at any point, but are most liable to follow surface leakage, as in tapped windings, or over a moisture soaked varnish. Discharges will leap over such surfaces and cause short-

circuits and grounds by the secondary effect of the following dynamo current in burning out the machine insulation. Designers, therefore, as far as possible, allow large margins of safety in the actual disruptive strength of the insulating layers.

In some cases the design of the machine will allow of the use of a considerable thickness of insulation resistance, but quite often only thin layers can be used. Tests must be made on different thicknesses of material and on a great variety of materials. It might appear easy to tabulate a set of results and adhere to it in practice, but from a single sample, a great variety of results may be obtained according to the conditions under which the test is made.

BOOK REVIEW

"The Clay and Shale Deposits of the Western Provinces" is the subject of a preliminary report by Heinrich Ries and Joseph Keele, '93, of the Geological Survey Branch, Department of Mines, Ottawa. The report is based on a season's investigations in the field, followed by a long series of laboratory work. It includes a summary of the existing conditions throughout the great western region, and contains a wealth of knowledge covering the many varieties of shales and clays included in the area. It emphasizes the advisability of the development of the clay industries, including paving, fire and common brick, drain tile and sewer pipe. The results of tests made upon numerous samples should be of interest to manufacturers. Analyses are given of clays from various points in Manitoba, Saskatchewan and Alberta, and valuable statistics regarding the formations of sandstone and shale in both the prairie and mountain regions also appear.

The report contains an account of the present state of the clay industry in the West, the brick plants in Winnipeg, Victoria and Vancouver; fire clay in Clayburn, B.C., and sewer pipe in Medicine Hat. It presents the total value of all clay products of the Western provinces for the years '07, '08 and '09, to be as follows:

	1907	1908	1909
Manitoba	$466,432	$265,091	$599,008
Saskatchewan	125,459	187,566	145,516
Alberta	353,672	240,384	442,486
British Columbia	306,137	344,446	470,442

The unparalleled demand of the present season is expected to be a great stimulus to the clay working industry.

The volume closes with chapters explaining methods of testing clays and a valuable treatise dealing with the nature and classification of clays. The report is supplemented by over sixty plates and maps.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published every month in the year by the University of Toronto Engineering Society

SUBSCRIPTION RATES

Per year, in advance	$2.00
Single copies	20

Advertising rates on application

Address all communications:

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

EDITORIAL

AN OLD QUESTION

The announcement has recently been made of the establishment of a University degree of Bachelor of Science in Agriculture. It may be conferred upon candidates who have completed a course extending over two years at the University and two years at the Agricultural College. One year's further training in the Faculty of Education leads to a specialist's certificate entitling the holder to teach both Science and Agriculture in a High School.

There are two classes of professional High School certificates: the assistants' and specialists'. The specialists' are issued only to the holders of the assistants'. All specialists are supposed to possess the academic standing in the general subjects required of those who hold an assistant's certificate. This academic standing is what has heretofore been a standard of admission in the Faculty of Education.

The degree of B.A.Sc., is inferior to the degree of B.A. in the matter of English, History, Latin, French, Greek, etc., and has not been recognized, therefore, of sufficient academic standing for a High School assistant's or specialist's certificate; and our graduates could not hope to obtain a teacher's certificate of either grade in the Faculty of Education.

Three years ago the Engineering Alumni Association took up the matter with the Superintendent of Education, and received a very unsatisfactory reply, in so far as the School man is concerned. The B.A.Sc. standard was not sufficient, and furthermore there was little or no demand in the High Schools for teachers of courses of instruction on subjects taught in the Faculty of Applied Science.

Since that time the interests of technical education have grown to demand instructors equipped with a knowledge of the various branches of engineering and of architecture. As an example, the Haileybury High School is searching for an instructor to take charge of a course of study in mining. Sudbury already has such a department in its High School. Substantial government aid is tendered these departments under a clause of the act entitling grants to industrial and agricultural departments of High Schools. The two examples of the new branch mentioned above command respectable remuneration. As technical education broadens its scope, Ontario and the other provinces will require similar officials in almost every High School with, it is to be hoped, similar salaries attached.

Viewing it from the School man's side, the graduating class yearly includes men who have a natural talent for teaching, and to whom such a field would be of interest. It is regrettable that the degree of B.A.Sc. is not considered tantamount with other degrees entitling the holders to admission to the Faculty of Education, so that he may receive the finishing touches prior to entering upon such work. The degree of B.A.Sc., however, is yearly spanning the gap between it and the entrance requirements mentioned above. It is now time for the Department of Education to examine the requirements and character of this degree, and for the graduates in Applied Science to agitate the reasonable reforms implied, not merely for their own advantage, but in the interests of the future which we look upon technical education to make for industry in general.

SCHOLARSHIPS

The research scholarship committee of the University of Toronto Engineering Alumni Association has made two awards. This has been done after numerous meetings for the consideration of applications, discussions of subjects, of their importance and of their suitability to the equipment, resources and time, that may be consigned to them. The selection now awaits the sanction of the faculty committee appointed to consider these scholarships, and of which the Dean is chairman. It is expected that the fellows will be at work by the opening of the term. They are both at hand and are making all preliminary preparations.

The awards were made to M. R. Shaw, '09, and W. P. Dobson, '10. These men, it will be remembered, were favorably considered last year, but were not donated scholarships, Mr. Shaw not having then had the advantages of a fourth year training, which he now possesses, and Mr. Dobson's subject, last year, although being timely and extremely important, not lending itself to the possibilities for the diligent research that would insure progress with the laboratory means at hand.

Mr. Shaw is a graduate in chemical engineering and has already been engaged in research work on various occasions. He was for a time in the employ of the Dow Chemical Co., of Midland, Mich, as chief assistant research chemist, and also with the Imperial Oil Co., of Sarnia, in like capacity. His thesis for the degree of B.A.Sc. last year was based upon, "The Substitution of Pure Oil for Linseed Oil in Paints." In his new undertaking as our research scholar he will confine his efforts to an investigation of the deodorization of the pine distillate that comes over after the extraction of turpentine. It is probable that a careful treatment of the subject will result in information of particular value. In the past years the price of turpentine, the chief and most important of the distillates, has decreased in commercial value to such an extent that a field for the various other distillates must enlarge correspondingly, thus increasing their value as commodities, so as to enable the producing plants to still carry on operations profitably.

Mr. Dobson will make an oscillographic investigation of the line disturbances due to switching on and off heavy loads in high tension systems. Since graduation he has been in the employ of the Toronto Hydro Electric System, and is familair with the conditions governing, and peculiarities invading, high tension operation. During his course in electrical engineering, his summers were spent on the design and operation of higher voltage apparatus.

His subject is one that is ripe for diligent examination. But little has heretofore been accomplished in an experimental way, and nothing at all has been done by way of investigating conditions on the particular lines carrying current at the extremely high pressures to which they are subjected in the transmission of power from Niagara to Toronto. It is upon these lines that Mr. Dobson proposes to work. He will endeavor to obtain more accurate and detailed information than is now available regarding the oscillations which are produced when large amounts of power are switched on and off a transmission or distribution circuit. His task will include a study of the effects of switching in upon the line various classes of machinery, his aim being to lessen the difficulties of operation and liabilities to interruption of service. Any unusual phenomena, e.g., line surges, lightning, etc., will probably be investigated. At any rate the subject affords Mr. Dobson ample opportunity for intimate acquaintance with the product of the "White Coal."

BOOK REVIEW

Primer of Scientific Management, by Frank B. Gilbreth. Published by D. Van Nostrand Company, New York; cloth, size 5″ x 7½″ 108 pages.

Those interested in scientific management and its many applications, and especially those who were fortunate enough to hear Mr. Gilbreth on "The Place of Motion Study in Scientific Management," in Convocation Hall, last March, will read with renewed interest his latest book on the subject. As the name suggests, it is an elementary treatment, the author imparting his information in the form of answers to questions. One enquiry, with its complete answer, follows its logical precedent, leading through an easily understood elucidation of the principles and their applications, the effect of scientific management on the workman himself, and the relation of the problem to other lines of activity.

The book will be of great assistance to managers, superintendents and foremen, who have realized that scientific management really secures greater production for the same or less effort, and who are endeavoring to introduce it into their business. It will be of greatest assistance, however, to those who are dubious concerning the movement, by removing from their minds all misapprehensions and suspicions that may have been caused by a study of the complex treatment given the subject in many comments by the technical press.

The engineer and the contractor do themselves injustices in being of the opinion that scientific management is for the manufacturer to consider and that little improvement need be expected in its application to engineering work. Every man who handles workmen, and every workman, as well, should be interested in the movement which aims at "square deal" and co-operation between workman and employer. The opening paragraph of Mr. Gilbreth's new book quotes Dr. Frederick W. Taylor thus: "The principal object of management should be to secure the maximum prosperity for the employer coupled with the maximum prosperity for each employee."

ERRATA

Referring to the examples of architectural design in the August number of Applied Science, the illustration described as a "Legislative Building for a Canadian Province" by J. H. Craig, and another termed "Design for Parliament Buildings" by H. H. Madill, were both mis-named. Each represents a design for a casino.

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Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 24 TORONTO, OCT. 1912 New Series Vol. VI, No. 6

LITERATURE AND MINING

By J. C. Murray, B.A., B.Sc.*

The relation of literature to mining has always been unsatisfactory. Although the literary workers of the past and of the present owe much to mining, that debt has neither been paid nor recognized. The existence of this debt needs no proof. I need only mention one of the several devices whereby ingenious authors relieve impecunious heroes. The English novelist creates rich gold mines in vague Australia: the American novelist usually prefers the Western States. However, there appears to be a well-grounded belief in certain literary circles—manufacturing circles is a better phrase, for the average novel is truly a manufactured article—that mining is the only honorable means whereby a man can become suddenly rich without selling his soul. And there is some real basis of fact behind this. Hence it is that in the pages of modern fiction many scores of bronzed, bearded, brawny lovers have returned from Australian "diggings" to crush their usually anaemic betrothed in their yearning arms. So also mining endows many a deserving character in fiction with unhoped-for affluence. Usually both authors and readers can lay claim to a profound and absolute ignorance of everything pertaining to the industry. This seems to apply even to the few authors who have written novels that purport to be devoted to mining matters. I remember one novel, the scene of which was laid in the Coeur D'Alenes. The author was—perhaps is yet—a lady. She set herself calmly to work to disorganize the bowels of the earth. She controverted all the fundamentals of geology, and introduced radical changes in stamp-mill practice. I remember that the stamps of a 10-stamp mill were described as weighing hundreds of tons. This sufficiently shows the degree of accuracy that can be expected from the lay writer.

The time has come when better things can be hoped for. Ten or twenty years ago the mining engineer was regarded (and here I use a cheerfully contemptuous phrase coined by an Eng-

*Editor of the "Canadian Mining Journal," in an address to the Engineering Society.

lish professor occupying an important chair in one of our universities) as an "educated plumber." The phrase loses half its value when it is not pronounced in the ultra-English dialect with substitution of "ah" for "er," the last syllable.

Times have changed. Even at universities the mining engineer is looked upon as a more or less intelligent person. The public have begun to think well of him and to expect much of him. And gradually, through a series of reactions, the public are becoming better informed as to mining. Hence I believe the day will arrive when aspiring novelists will no longer dare to take undue liberties with the principles and practice of mining. Half a century ago, for instance, Mrs. Humphrey Ward could have misplaced North Bay with impunity. But to-day she is suffering for her lack of consideration. Similarly with mining. The author who can now perpetrate the grossest solecism about mining without suffering for it will be brought severely to book by the more critical reader of the future.

These generalities, however, are not what I intended to inflict upon you. With some indefinite intention of showing how much to interest him specially the mining man may find in general literature, I began to throw together a few notes. Lack of time and pressure of work have made it quite impossible for me to put these notes in coherent form. I must ask you to accept them as they are.

Perhaps in any library the department of travel will be found richest in allusions to mining. But many historical works contain much that interests the mining engineer, those of Parkman and Prescott, for instance, being liberally sprinkled with references to mining matters. Search for such references is hardly to be considered a worthy object in itself, but encountering them certainly adds zest to one's reading.

Lately I have been re-reading a few books that occupy places of honor in my small library.

The first book that I wish to glance over is the English translation of one of the greatest books of travel ever written—the "Travels of Marco Polo, the Venetian." I may refresh your memories by reminding you that Marco Polo was born in the year 1254. His father and his uncle were dauntless travelers. Together, they spent almost nine years in traveling between Venice and Cathay, where they visited the mighty Kubla Khan, whom Coleridge immortalized. A vivid imagination indeed would be required to picture the perils and hardships of that long journey into mysterious and unknown regions. It is no wonder that young Marco Polo's ambition was roused by the travelers' tales.

Marco's father and uncle returned to Venice in 1269. They had been commissioned by Kubla Khan to bring back with them 100 missionaries to operate upon the Cathaians. This they could not do without the permission of his Holiness the Pope. It hap-

pened that there was a papal interregnum, no successor to Clement IV. having been elected. After waiting for two years for the new Pope, Gregory X., to be elected, the Polos succeeded in getting two Dominicans. The hardships of travel very soon frightened these two worthies, and the three Polos—father, son, and uncle—started without them on their tremendous journey across Asia. Four years it took them to reach Shangtu, where Kubla Khan held court. Young Marco Polo immediately achieved popularity and rose in honor and wealth until he became one of the most important men in Kubla Khan's wide dominions. Not until the year 1295, after twenty-four years of absence, did the Polos see Venice again. The book that has come down to us was dictated to a Genoese scribe by Marco Polo during his imprisonment for a political offence, four years after his return. Cameras, note books and fountain pens were not current in those days. The traveler, therefore, had to trust to his memory. And it takes one's breath away to think that Marco Polo could remember details of his travels so accurately that much of his description holds good to-day.

We have to do, however, with Marco Polo's allusions to mining and kindred matters. It will not be necessary to go further into biographical details. Chapter IV. of Marco Polo's book opens with a reference to a "rich mine of silver," within a castle named Paipurth in Armenia Major, and closes with a paragraph on the Zorzaman (the Kingdom of Georgia) oil springs—the marvellously rich Baku oil field of to-day. "A fountain of oil," says Marco, "discharges so great a quantity as to furnish loading for many camels. The use made of it," he continues, "is not for the purpose of food, but as an unguent for the cure of cutaneous distempers in men and cattle, as well as other complaints; and it is also good for burning. In the neighboring country no other is used in their lamps, and people come from distant parts to procure it."

It is impressive to learn that the Baku gushers have been supplying the needs of a large population for many centuries. As I do not intend to introduce any statistics into this brief talk, I shall merely state that the Baku fields in Southern Russia are to-day of enormous commercial importance.

The extensive kingdom of Badakhshan, near the modern Afghanistan, is described by Polo as being rich in minerals. "In this country," he writes, "are found the precious stones called balaso rubies of fine quality and great value, so called from the name of the province. They are embedded in the high mountains, but are searched for only in one, named Sekinan. In this mountain the king causes mines to be worked in the same manner as for gold or silver, and through this channel alone they are obtained, no person daring, under pain or death, to make an excavation for the purpose, unless as a special favor, he obtains his majesty's license. Occasionally the king gives them as presents to strangers who pass through his dominion, as they

are not procurable by purchase from others and cannot be exported without his permission. "His object in these restrictions," as Polo quaintly expresses it, "is, that the rubies of his country . . . . . . should preserve their estimation and maintain their high price; for if they could be dug for indiscriminately . . . . . . so great is their abundance, that they would soon be of little value." It must comfort the spirit of that departed king to know that rubies are still embarrassingly precious. "There are mountains likewise in which are found veins of lapis lazuli . . . . the stone which yields the azure color, here the finest in the world. The mines of silver, copper and lead are likewise very productive."

As Marco Polo proceeded through each succeeding province or kingdom he made mental notes of its resources. In many cases, as in that quoted above, he dwells especially upon the minerals. Chalcedony, onyx and jasper are frequently mentioned, silver less frequently, but gold is often referred to.

Near the capital city Kain-du, in Eastern Tartary, the lake pearl fisheries attracted Polo. Here also the ruler restricted the search for these precious articles, for fear of glutting the market. This monopoly and close control of mining was characteristic of the times, and was given the color of wisdom by the very limited markets.

In consequence of the abundance of gold found in the rivers of the province of Karazan (the modern Chinese province of Yun-nan) gold was worth only six times as much as silver. Even then, there was a profitable business in exchanging silver for gold and vice versa in countries where the relative value of each metal was different. Five days' journey westward from Karazan lay the province of Kardandan. Here is an interesting excerpt:

"The currency of this country is gold by weight, and also the porcelain shells. An ounce of gold is exchanged for five ounces of silver . . . . there being no silver mines in this country, but much gold, and consequently the merchants who import silver obtain a large profit. Both the men and women," adds Polo, "have the custom of covering their teeth with thin plates of gold, fitted with great nicety." A form of vanity that survives to this day and generation.

Perhaps I have quoted enough to show that Marco Polo was consistently interested in the resources of mediaeval Asia.

I shall pass now to an author of a quite different type and of a later date—Mr. Samuel Pepys.

(*To be continued*)

ENGINE BALANCING

By J. M. Duncan, B.A.Sc.

An engine is said to be in perfect balance when the centre of gravity of its moving parts is a fixed point. As force is required to displace the centre of gravity of any system of bodies, another statement of this is that an engine is perfectly balanced when no resultant forces exist tending to move the engine framing bodily in any direction.

The forces generated by an unbalanced engine are commonly said to give rise to vibrations if the engine be in a boat, an automobile, or on any kind of elastic foundation; and to cause pounding or "nosing" if on a locomotive.

The amount of these vibratory or pounding forces is sometimes very large, and means must be sought to overcome them. On board ship the problem is most important—the discomfort of passengers, or, in a war vessel, the unsteadiness of the ship as a gun platform, being undesirable features, the result, as a rule, of unbalanced engines. With locomotives, as Mr. Macauley has pointed out,[1] the forces are often so great as to cause rail fracture, and must be very prejudicial to the machine itself.

Forces arise in engines through the centrifugal force of any unbalanced revolving parts, e.g., an unbalanced crank pin or connecting rod end. Centrifugal forces can always be balanced, however, by the use of counterweights, and are generally so balanced. But other forces than these arise in the reciprocating engine. Force is required to accelerate any body, and the reciprocating parts of an engine are continually being accelerated, for the velocity of the piston and attached weights is continually changing if the rotation of the crank pin is uniform. It might be said that this force comes from the steam in the cylinder. This is so, but a disturbance results nevertheless; for in Fig. 1 if A represents area of piston, and p represents cylinder head pressure of steam in pounds per square inch, then the total upward pressure tending to lift the cylinder from the columns is $p \times A$ lbs. The total pressure on the piston in a downward direction is likewise $p \times A$, but of this total pressure a part $p_1 \times A$ is absorbed in giving acceleration to the piston, crosshead and part of the connecting-rod while the remainder, or $p_2 \times A$, is transmitted through the rods and crank to the main bearings; $p_2 \times A$ is then the only downward force which opposes $p \times A$ in the upward sense; that is, there is an unbalanced force of $-p_1 \times A$ tending to raise the engine from its foundations; and a similar downward force will exist during the upward stroke.[2]

To ascertain the amount of this force, we must find an expression for the acceleration of the reciprocating weights. The expression is obtained by setting down an equation representing the position of the crosshead E (Fig. 2) in terms of θ, l and r, the latter two

1 "Locomotives, Steam vs. Electric." R. V. Macauley, B.A.Sc. in "Applied Science," Vol. VI. No. 4, p. 145.
2 Bauer and Robertson---"Marine Engines and Boilers," pp. 82---105

being conveniently combined in the symbol $a = \frac{r}{l}$. This equation being differentiated once with regard to time gives the velocity of E and twice with regard to time gives the acceleration of E. The result is brought into the form of a series as below, for convenience of treatment — (α = acceleration of E).

$$
\begin{aligned}
\frac{\alpha}{r\omega^2} = {} & \operatorname{Cos} \theta \\
& + \operatorname{Cos} 2\theta \left(a + \frac{1}{4} a^3 + \dots\right) \\
& - \operatorname{Cos} 4\theta \left(\frac{1}{4} a^3 + \frac{3}{16} a^5 + \dots\right) \\
& + \operatorname{Cos} 6\theta \left(\frac{9}{128} a^5 + \dots\right), \text{ etc., etc.}
\end{aligned}
$$

That is, the piston has harmonic motion, harmonics of the first and all even periods being present. If the engine be in a ship it is

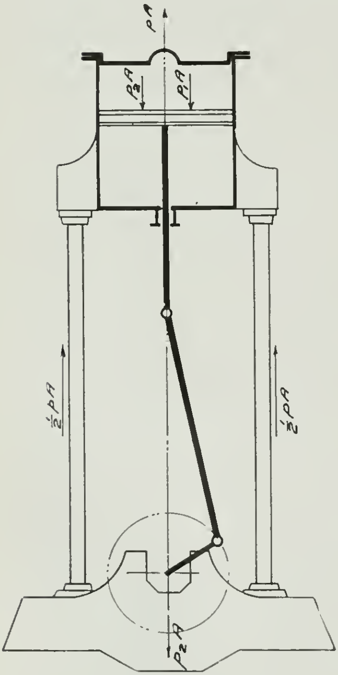


Fig. 1

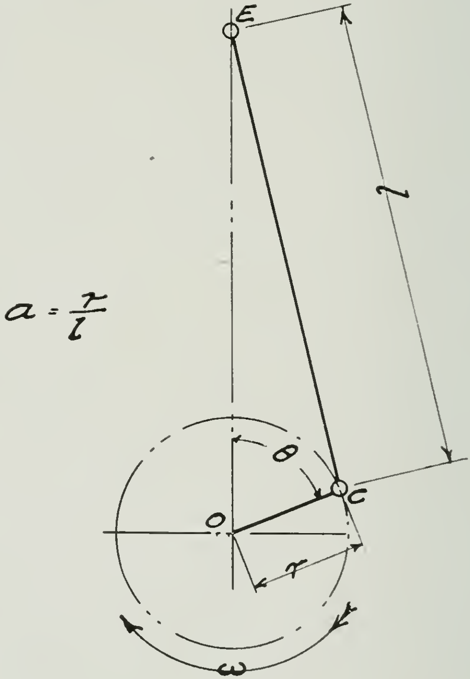


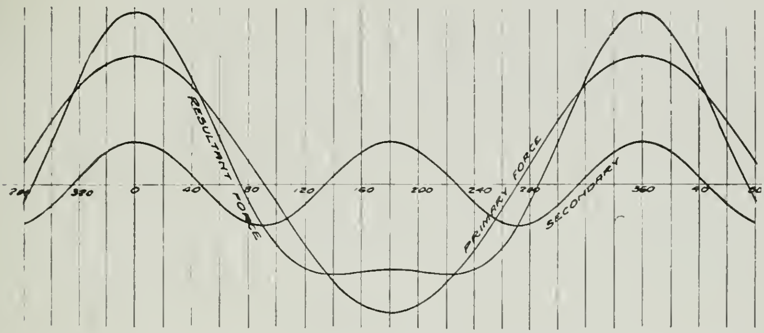
Fig. 2

most favorably located for making these harmonics evident to the senses, for the elastic structure of the ship can respond theoretically at least to vibratory impulses of any period; and vibrations of the sixth period actually have been found in a ship. Vibrations of higher periods than the second, however, are so small as to be quite

negligible in practice, and hence it is usual to speak of an engine as being "completely balanced" if it is balanced for the first and second periods, that is if no free forces or couples exist having positive "maxima" either once or twice during a revolution. (See Fig. 3) Thus we reduce the expression for α to the following:

$$\frac{\alpha}{r\omega^2} = \text{Cos}\ \theta + \text{Cos}\ 2\ \theta\ (a + \frac{1}{4}\ a^3 + \ldots),$$

and evidently for values of $a = \frac{1}{3.5}$ or $< \frac{1}{3.5}$ the following



CURVES REPRESENT FORCES DUE TO AN UNBALANCED RECIPROCATING WEIGHT SECONDARY FORCES ARE HERE FOR A RATIO $a = \frac{7}{7} = \frac{1}{3}$

Fig. 3

approximation is sufficiently close — where the maximum error involved is 1%.

$$\frac{\alpha}{r\omega^2} = \text{Cos}\ \theta + a\ \text{Cos}\ 2\ \theta$$

or $\alpha = r\omega^2\ (\text{Cos}\ \theta + a\ \text{Cos}\ 2\theta)$.

Now, $force = \dfrac{acceleration \times mass}{g}$

so $f = \dfrac{mr\omega^2}{g}\ (\text{Cos}\ \theta + a\ \text{Cos}\ 2\ \theta)$ if f = force due to acceleration of mass "m".

Symbols used throughout this article—

m = total mass of reciprocating weights actuated by one crank.
M = total mass of revolving weights actuated by one crank.
f = force generated by m.
F = force generated by M.
ω = angular velocity of crank (assumed constant, since if the centre of gravity is a fixed point for one speed it is a fixed point for all speeds).
α = acceleration of any part (either radial for revolving, or linear for reciprocating points).
r = length of crank.
l = length of connecting rod. $a = \frac{r}{l}$
θ = angle turned through by the crank from any reference direction.

We have thus a formula for the force due to the piston and all rigid attachments. The effect of the connecting-rod has also been determined by various investigators, and it has been found capable of very simple treatment. In Fig. 4, G is the centre of gravity of

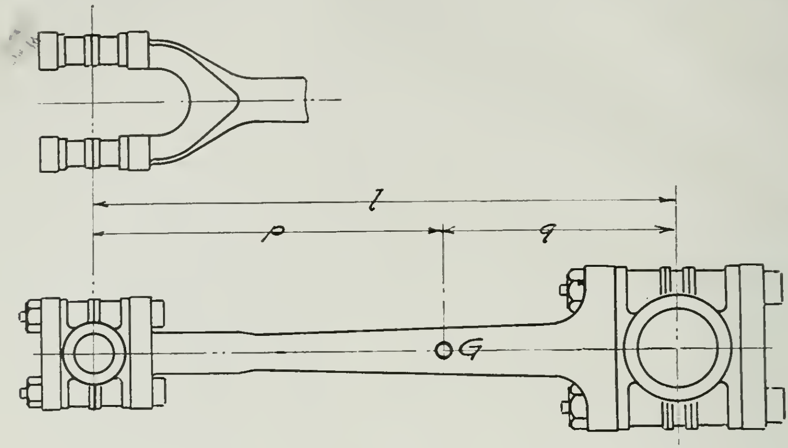


Fig. 4

the rod and m_c the mass. Then the net effect of the connecting-rod mass, m_c, is that a mass, $m_1 = m_c \frac{q}{l}$, may be imagined concentrated at the crosshead and the remainder, or a mass, $m_2 = m_c \frac{p}{l}$ at the crankpin. Thus m_1 may be included in m, the total recipro-

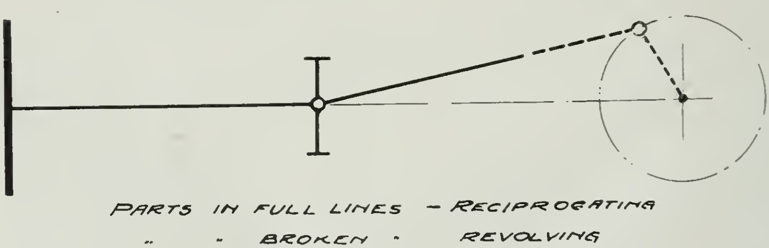


Fig. 5

cating masses, and m_2 in M the total revolving masses. The usual approximation for marine type rods is $q = 0.4l$. Fig. 5 shows diagrammatically the classification of weights now obtained.

It remains now only to set down the formula for the force F, due to the centrifugal effect of the revolving weights, a force which tends to move the engine framing, hence a distributing force in the balance of the engine. The expression is obtained here also

from the acceleration of the masses involved, and $F = \frac{Mr\omega^2}{g}$, since $a = r\omega^2$, for uniformly rotating weights.

Dalby's Graphical Representation of Formulæ

Rewriting the expression $\frac{mr\omega^2}{g}$ (Cos θ + a Cos 2 θ) thus

$$-\frac{mr\omega^2}{g} \text{ Cos } \theta \qquad (1),$$

$$+\frac{mr\omega^2}{g} \, a \text{ Cos } 2\theta \qquad (2),$$

the first is the projection on the line of stroke of centrifugal force $\frac{r\omega^2}{g} m$ due to the mass m moved by the crank OA (Fig. 6), r units long, which has moved with an angular velocity ω through the angle θ from the line of stroke. It then may be represented by a

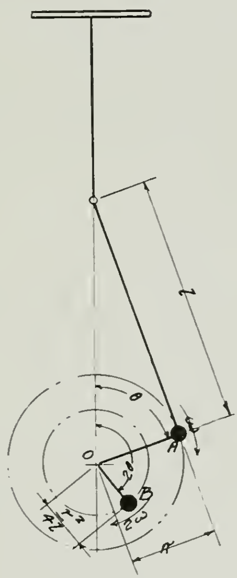


Fig. 6

vector parallel to OA. The sense adopted is O to A, positive, and the magnitude is the force $\frac{mr}{g}$ ω^2 $Cos\ \theta$, to any chosen scale.

The second part of the expression may be rewritten thus

$$\frac{mr\omega^2.}{g} \, a. \, Cos\ 2\theta = \frac{mr\omega^2.}{g} \frac{r}{l}. \, Cos\ 2\theta = \frac{m\,(2\omega)^2}{g} \cdot \frac{r^2}{4l}\ Cos\ 2\theta.$$

This is the projection on the line of stroke of a force due to m actuated

by a crank $\frac{r^2}{4l}$ units long, which has moved with an angular velocity 2ω through the angle 2θ from the line of stroke. The vector is drawn as directed for OA. Fig. 6 shows also that a primary crank and a secondary crank may be imagined, the latter being $\frac{r^2}{4l}$ long, concentric with the former and revolving twice as fast.

Here it is well to note the effect of doubling ω. Primary forces are quadrupled, their period halved; secondary forces quadrupled,

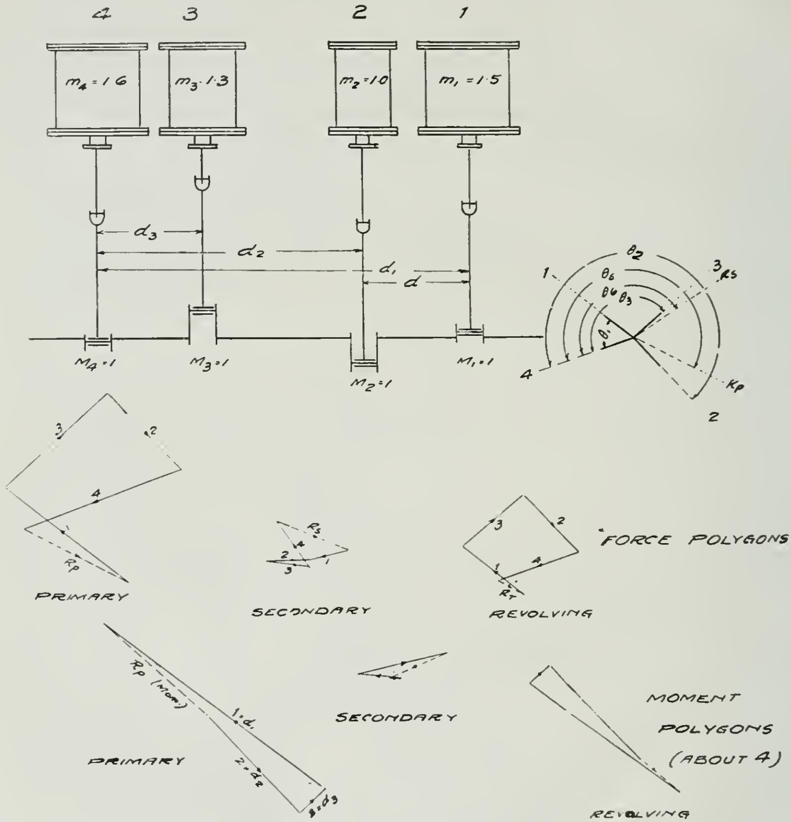


Fig. 7

their period quartered. Hence an increase of speed means a proportional increase of forces of all periods; but the higher periods rapidly become so short that the engine mass as a whole can not respond to them. The stresses are, however, increasingly serious, and at the same time very rapidly alternating.

To resume—if we have several cranks, as in Fig. 7, we may

find the resultant force in the engine by means of vector polygons. The resultant of the vectors drawn — the closing line of the polygon —will represent the free or unbalanced force in the engine due to the arrangement of weights, crank angles and cylinder spacing shown. This resultant means that the engine would be balanced for primary force by a reciprocating mass, equal to m_{R_p}, driven by a crank at an angle θ_5 from the reference line, which latter may always be chosen coincident with any of the cranks since the length of the resultant is unaffected by its position. Here the reference crank is crank No. 4. Secondary balance could be secured by the addition of a crank which would cause the secondary force f_{R_s} and whose crank angle would be θ_6 as shown. Revolving force polygons will be drawn in the same manner as the primary polygons above, but, while they may look similar it must always be remembered that revolving and reciprocating balance diagrams represent essentially different kinds of forces. (See pp. 220 ff.).

Note that in all expressions for forces and moments the factor $r\omega^2$ is present. We therefore, in drawing polygons may make the sides proportional to weights $\frac{m}{g}$ only. Then the resultant force f_{R_p} is $f_{R_p} = m_{R_p} \frac{r}{g} \omega^2 (Cos\ \theta + a\ Cos\ 2\theta)$ where $\frac{m_{R_p}}{g}$ is the resultant weight.

Forces and Moments

In a single crank engine neglecting the valve weights, forces are developed only in one plane—viz., that in which the crank pin rotates and containing the cylinder axis.

If there be two cranks, forces will be generated in two planes. If the cranks are not parallel a moment will exist $= f_2 \times d$ for reciprocating and $F_2 \times d$ for revolving weights if moments are about No. 1 (See Fig. 7), considering at present only cranks 1 and 2. The position of the reference plane will effect the amount of the moment if the forces are not balanced, but if the forces are balanced a free couple may exist. This, of course, is independent of the position of the reference plane. Since it acts in the plane of the cylinder and draft axis, this couple will have the tendency to tilt the engine bodily in this plane; hence has been termed by Inglis[1] a "tilting couple." Individual forces have no such tendency and are termed "hammering forces." Evidently a couple is a disturbing element and no engine is balanced in which a free couple exists.

Then in all multi-crank engines (including single-cylinder engines if the valve weights are considerable) for complete reciprocating balance the Primary and Secondary force and moment polygons must all close, and for revolving balance the force and moment polygons must likewise close.

1. John A. Inglis, "Balancing the Four-Crank Marine Engine," *Engineering*, June, 1911.

Reciprocating and Revolving Balance

Consider the nature of the forces f and F.

$$f = m\frac{r\omega^2}{g}\ (Cos\ \theta + a\ Cos\ 2\theta) \qquad (1)$$

$$F = M\ \frac{r}{g}\ \omega^2 \qquad (2)$$

Here f, due to reciprocating weights is constant in direction always having the cylinder axis as its line of action, but varies with Cos θ and Cos 2θ in amount; whereas F, due to revolving weights is constant in amount and variable in direction, always having the centre line of the crank for its line of action. Consequently revolving weights can not balance reciprocating weights, and vice versa.

To illustrate, suppose we re-write, (2),

$F = M\ \frac{r}{g}\ \omega^2\ Cos\ \theta + M\ \frac{r}{g}\ \omega^2\ Sin\ \theta$ (vectorially), or if M be here a counterweight fitted 180° ahead of (i. e., opposite to) the crank, $F = M\ \frac{r}{g}\ \omega^2 \left\{ Cos\ (\theta + 180) + Sin\ (\theta + 180) \right\}$

$$- M\ \frac{r}{g}\ \omega^2\ (Cos\ \theta + Sin\ \theta).$$

Considering only counterweights and reciprocating weights we shall have $f + F = \frac{mr\omega^2}{g}\ (Cos\ \theta + a\ Cos\ 2\theta)$

$$- \frac{Mr\omega^2}{g}\ (Cos\ \theta + Sin\ \theta)$$

and if $M = m$.

$$f + F = \frac{mr\omega^2}{g}\ a\ Cos\ 2\ \theta - \frac{mr\omega^2}{g}\ sin\ \theta$$

$$f + F = \frac{mr\omega^2}{g}\ (-Sin\ \theta + Cos\ 2\ \theta),$$

which indicates merely a shift in phase of the primary reciprocating part of the force f; that is, if the engine be a vertical one, reciprocating forces are now acting horizontally, instead of vertically, as before. In a ship horizontal vibrations are usually of less amplitude for the same force than vertical vibrations. Therefore when nothing else can be done (as, for instance where an existing multi-cylinder engine is out of balance) it may be advisable to fit such weights. (See Bauer & Robertson, "Marine Engines and Boilers," pp. 92-100.). Note, however, that for a horizontal engine the fitting of such a counterweight would be the worst possible thing to do. Forces which formerly exerted a shear on the foundation bolts now produce a pounding on the foundation, or in the case of a locomotive, rail pounding which would be positively ruinous.

There is a possible compromise in the fitting of revolving counterweights—

If $M = \frac{m}{2}$, we shall have

$$f + F = \frac{mr\omega^2}{g} \, Cos\ \theta - \tfrac{1}{2} \frac{mr\omega^2}{g} \, Cos\ \theta$$

$$- \tfrac{1}{2} \frac{mr\omega^2}{g} \, Sin\ \theta + \frac{mr\omega^2}{g} . \, a \, . \, Cos\ 2\ \theta$$

$$= \tfrac{1}{2} \frac{mr\omega^2}{g} \, Cos\ \theta - \tfrac{1}{2} \frac{mr\omega^2}{g} . \ Sin\ \theta$$

$$+ \frac{mr\omega^2}{g} \, a \, Cos\ 2\ \theta$$

The effect of such a counterweight is the reduction of the *primary* reciprocating forces by ½, incidentally causing the combined primary forces to act as though caused by a mass $\frac{m}{2}$ revolving in the direction opposite to the crank. Secondary forces are seen to remain as before. The practical difficulty of fitting large revolving weights however, make it generally impossible to do more than balance the revolving weights alone and even this is difficult with the single cylinder engine.

Balancing Possibilities of Various Types of Engines

(1) The Single Crank Engine

(a) Centre Crank Type.—The best balance practically attainable is revolving balance only as noted above. The counterweights will be conveniently incorporated in the crank disc and it will generally be found difficult to put in enough weight to balance completely revolving forces.

(b) Side Crank Type—If revolving forces are balanced, a revolving couple will be introduced due to the overhang of the crank pin.

(2) The Two Crank Engine

(a) Two Centre Cranks.—Revolving balance is now easier to obtain. With the usual arrangement of cranks at 90° (for the steam engine) less total addition of weight need be added than for two independent single crank engines. Fig. 8 shows that if

M' = mass of total revolving counterweight

M = revolving mass for 1 crank, then $M' = M\sqrt{2}$. The saving in weight, $\frac{M}{g}(2 - \sqrt{2})$, is obtained by sacrificing perfect balance of moments but is well worth while. Fig. 9, illustrating a small compound engine built by the Collingwood Shipbuilding Company, shows how difficult it would be to put any more weight in this marine engine where the pinch wheel, which is used as a counterweight, has to clear the deck. Two balance wheels are used and they are placed as far apart as possible.

With the cranks at 90°, primary reciprocating balance is impossible; secondary forces are balanced, however, if the weights are equal. If the cranks are at 180°, primary forces are balanced

and a primary couple and secondary force and couple unbalanced. If with this arrangement, the cylinders are on opposite sides of the shaft, as in the small double-opposed gasoline engine, forces of all periods are balanced, as any force developed on the one crank is offset by an equal force acting in the opposite sense on the other.

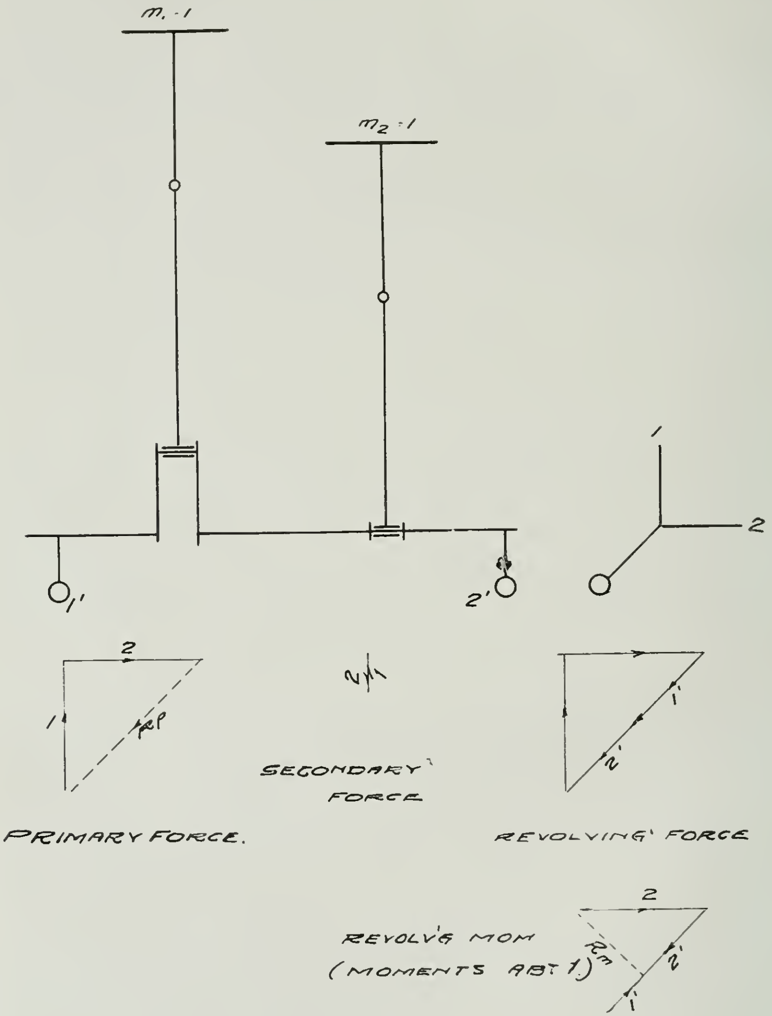


Fig. 8

A couple will be the only disturbance, and to eliminate this would require a split connecting-rod, enabling the two cylinders to be brought in line.

(b) Two Side Cranks.—The most important example is the

outside cylinder locomotive. Cranks are here at 90°. Revolving forces can be balanced by counterweighting each wheel opposite the crank pins but a small resultant moment still exists. This cannot be avoided unless cranks are differently arranged. Undoubtedly, however, hammering forces are much more serious than this small couple, which might here be called a "nosing couple" as it tends to produce "nosing" of the engine. But this couple will be so small compared to that produced by the reciprocating forces as to be negligible. Evidently reciprocating forces are horizontal in their direction, hence can not cause rail pounding; but since couples

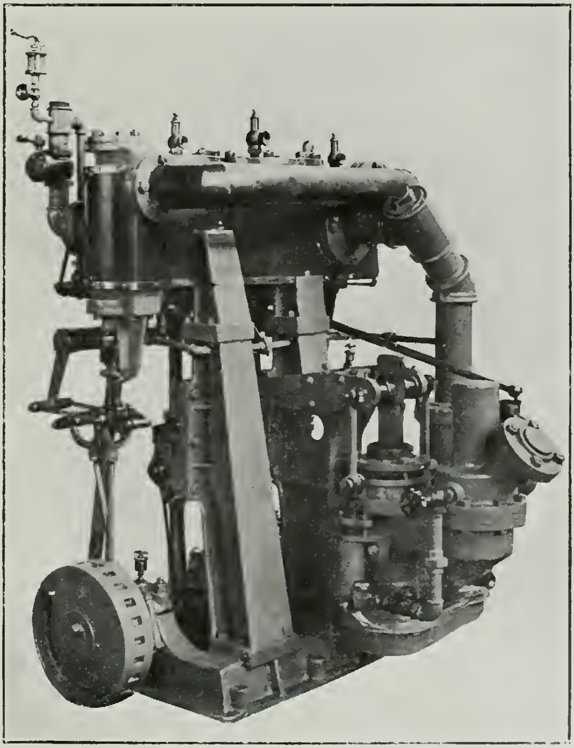


Fig. 9

can not be balanced, "nosing" will result, the couples tending to sway the front of the locomotive from side to side. There will be a "natural period" for this swaying and when the period of any of the couples coincides with this natural period the nosing will be a maximum. Thus, at some speeds it will be unnoticeable, while at a lower speed possibly excessive.

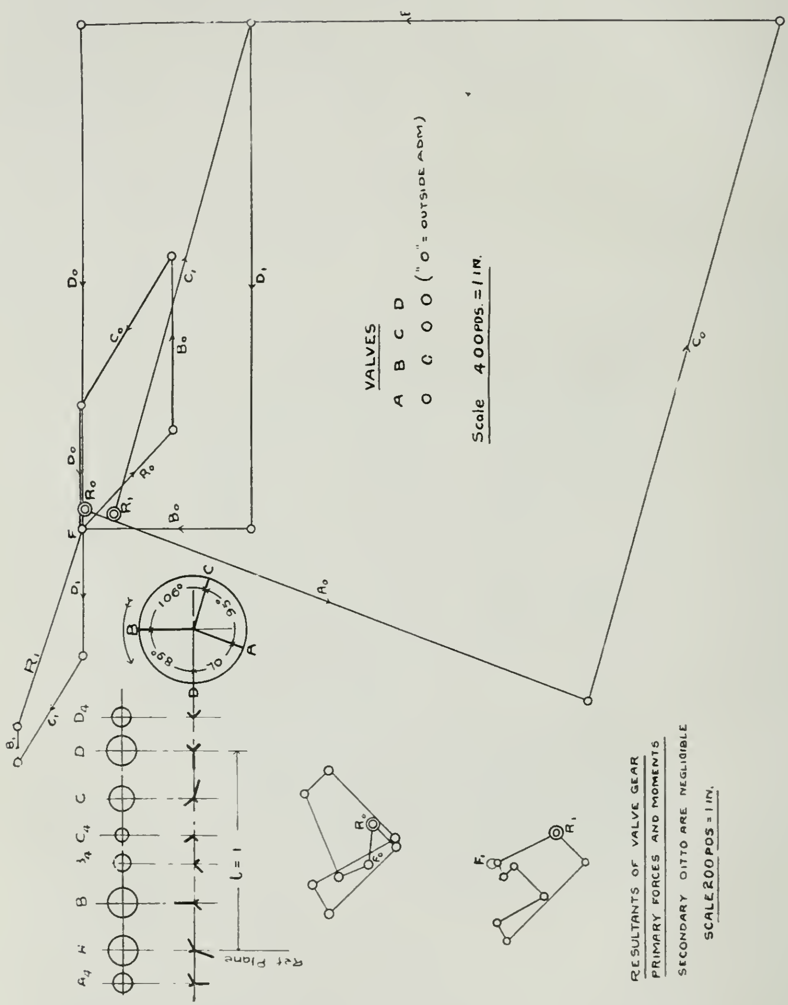

VALVES
A B C D
O C O O ("O" = OUTSIDE ADM)
Scale 400 PDS. = 1 IN.
RESULTANTS OF VALVE GEAR
PRIMARY FORCES AND MOMENTS
SECONDARY DITTO ARE NEGLIGIBLE
SCALE 200 PDS = 1 IN.
Ref Plane
l = 1

Fig. 10

PRIMARY

	Cylinder Arms	Weights	Moments	Valve Arms	Weights		Moments	
		0	1		Ahead	Astern	Ahead	Astern
A	0	1130	0	—0.183	95	35	— 17	— 6
B	0.242	1460	354	+0.439	100	36	+ 44	+16
C	0.716	1495	1079	+0.574	100	36	+ 57	+21
D	1.000	1063	1065	+1.183	100	36	+118	+43

SECONDARY

	Cylinder Arms	Weights	Moments	Valve Arms	Weights		Moments	
		0	1		Ahead	Astern	Ahead	Astern
A	0.	283	0	—0.183	4	1	0	0
B	0.242	365	78	+0.439	4	1	2	—
C	0.716	367	262	+0.574	4	1	2	—
D	1.000	266	266	+1.183	4	1	5	1

(3) Three Crank Engines

(3) Three Crank Engines.—Only two arrangements of cranks are attempted with this engine—the usual being cranks at 120° the less common having the centre crank 180° from the other two. If the latter arrangement is adopted for balancing considerations. the centre crank weights are twice as heavy as on each of the outer cranks; then primary forces and moments are balanced. This arrangement with the double-acting steam engine has the disadvantage of a poor turning moment; with single acting gas engines it would be difficult to sufficiently increase the centre weights. The turning moment of the double acting engine with cranks at 120° is very good and balance is secured for forces of every period but the sixth and multiples of the 6th, if the three cranks have equal weights, as may be seen by inspection of the complete formula on page 214.

For example, where $\theta = 120°$; $2\,\theta = 240°$, and $4\,\theta = 480°$ equivalent to 120°. But $6\,\theta = 720°$ and corresponds to 0°, and the three sixth-period cranks coincide; polygons for all other periods are equilateral triangles.

Equal reciprocating weights are secured by thickening the piston of the high pressure and intermediate pressure cylinders in a triple-expansion engine; or, if the air pump be lever driven from the low pressure crosshead, thus virtually reducing the reciprocating L. P. weights, usually the M. P. becomes the heaviest weight and the H. P. need be increased very little. Revolving balance of forces is generally all that is attempted, as this can very conveniently be obtained by loading the pinch wheel. It will result in a constant unbalanced revolving couple, but, as reciprocating couples are unbalanced, this is usually neglected. To extinguish it would require counter-weights added in two planes.

Of perhaps not more than a theoretical interest is a three crank engine with two of the cranks on one side and a centre crank with weights equal to the sum of the other two, but "opposed," *ie*, on the opposite side of the shaft. This is merely a development of the double-opposed engine; couples are avoided and consequently the engine has absolutely perfect balance.

(4) Four Crank Engines.—Every additional crank in the engine means one more side to all vector polygons, and consequently greater balancing possibilities. With four cranks we have four-sided force polygons and three-sided moment polygons. We are now at liberty to change the crank angles as we please, and still, by changing also the weights, have both the poise and moment polygons of the first period close. Thus it will be possible to close a third polygon at the same time, i. e., to balance secondary forces as well.

It would not be permissible to modify crank angles if the turning moment were thereby made very uneven, but it has been proved that the angles which give the best balance for a four crank engine give also the best turning moment. Four cylinder locomotives are sometimes adopted on account of the superior balance possible, and marine engines for passenger boats are generally of the four crank type for the same reason. Fig. 10 shows a marine engine balanced for primary and secondary forces and primary moments, the method followed being described in detail.

(5) Five-Crank Engines.—Imagine two similar three-crank engines placed on the same bed plate in a manner such that their constant unbalanced couples oppose one another. Then, since forces in each are balanced completely (see p. 225) and the couples are equal and opposite, the engine is completely balanced. If now the two engines are made to approach one another till the centre cylinders coincide, the balance will be as before. Thus we obtain a five-crank engine completely balanced for all forces and couples except those of the sixth, twelfth, etc., periods. Fig. 11 illustrates a completely balanced five-cylinder engine. It will be

noticed that weights do not have to be equal as in the three-crank type.

We have now reached a type of engine with practically perfect balance. If more cranks are used, the balance can hardly be improved. In fact it is seldom that more than four cranks are used as the balance obtainable with them is quite good enough for all practical purposes.

Effect of the Valve Gear of an Engine

Since the valve gear of a steam engine is actuated by cranks in the form of eccentrics, it may be treated exactly as the main weights. The connecting rod ratio for the eccentric is so small, however, as to render secondary forces quite negligible.

As the valve gear weights are relatively small compared with the main weights, a common procedure is to treat them as purely

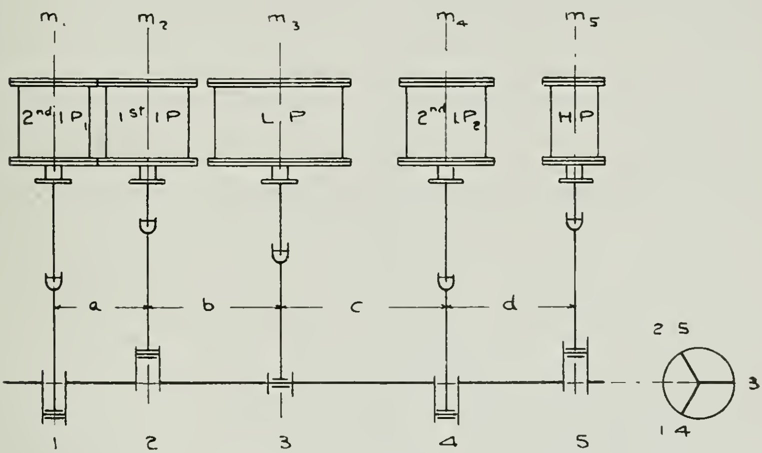


Fig. 11

revolving weights to be balanced together with the main revolving weights. This is a simple method and does not cause any large error in the balance of the engine; but an engine so balanced will generally have considerably more extra weight in the reciprocating parts than would be the case if the force and moment polygons included sides representing the valve gear as well as main weights. The advantage of the latter method is illustrated in Fig. 12. The Yarrow-Schlick-Tweedy System is to treat the valve gear weights separately as first mentioned above; then a spacing of cylinders and ratios of crank angles and weights which are symmetrical, are found to give the desired balance. By including sides representing the valve gears in the main weight polygons this symmetry is lost, but the saving in weight may be considerable. Accurate balance of a four-crank engine by the latter method is obtained by manipu-

lating the force and moment polygons for several trial values of the variables involved, viz., crank angles, weights and cylinder spacing,—a trial and error method. The elimination of the valve gear from the problem, however, makes it possible to arrive directly at the proper values to give the required balance. The objection to the method is the unnecessary addition of weight involved. The Taylor and Inglis diagrams are very useful in preliminary investigation. Nothing final, however, is accomplished, the force and moment polygons must still be manipulated and the best values of the unknowns found by trial and error.

Balancing a Four-Crank Marine Engine

We first estimate and tabulate the weights of all moving parts of the engine so far as at present designed. Any simple system of symbols such as used on the diagram (Fig. 10) will be of service.

To take an example, let the engine be of the 4-cylinder triple expansion type, the valves being all outside admission and driven by

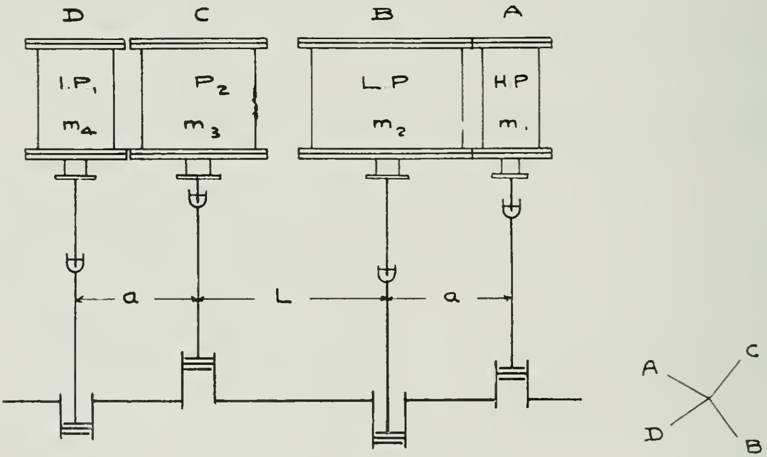


Fig. 12

Stephenson link motion. The connecting rod is four times the length of the cranks, that is, $a = \frac{r}{l} = \frac{1}{4}$. Note that an inside admission valve is actuated by an eccentric 90° ahead of that which operates a valve with outside admission. It is always well to show diagrammatically the positions of the various eccentrics and cranks as in Fig. 10. There are no auxiliaries driven from this engine. The heaviest piston will be the one whose weight will be unchanged throughout the problem, so it may be at once designed; for our engine it will be the I. P. piston. Thus, we have to estimate the weights of the I. P. piston, and all crossheads, connecting rods, piston rods, cranks and valve gear.

Estimating the Valve Gear

(The following is extracted from Taylor's paper).

Since these weights are included in the main polygons, they must be reduced by virtual weights having the travel of the piston for reciprocating weights and revolving with the crank for revolving

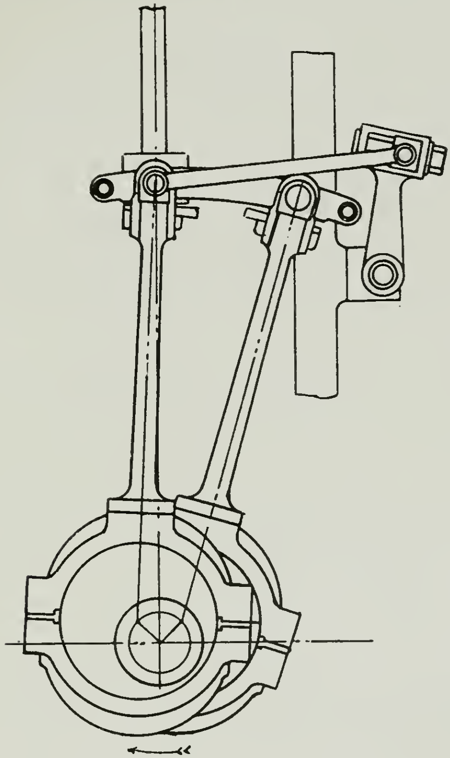


Fig. 13

weights. These virtual weights are obtained very simply by multiplying by the ratio

$$\frac{\text{Travel of Valve}}{\text{Stroke of Piston}}$$

Fig. 13 shows an ordinary valve gear, the data for it being as follows:—considering one of the L. P. cylinders of the example.

Dimensions

Stroke of engine	22″
Connecting-Rod Ratio, "*a*"	¼
Travel of Valve	5″
Length of Eccentric Rod	52″
Angular advance of ahead eccentric (outside admission valve)	135°

Weights

Item No.	*Description*	*Pounds*
1.	Valve and rigid attachments	292
2.	Radius Links	90
3.	Drag Links	56
4.	Each eccentric rod and strap	147
5.	Top half of rod	67
6.	Eccentric Sheave	65

Now, separate these weights into ahead and astern, reciprocating and revolving. Item 1 is all reciprocating and belongs entirely to the ahead gear. The radius links, item 2, are divided equally between ahead and astern. Of the drag links one end is at rest, the other reciprocating with the head gear. As to the eccentric rod and strap—there is one for each gear, ahead and astern. This being a connecting rod we concentrate its weight at the two ends, regarding the bottom half as concentrated at the eccentric centre and revolving. The sheaves are all revolving. The results are shown in the accompanying Table I.

Table 1. Valve Gear

Item	Total Weight	Ahead Gear		Astern Gear	
		Reciprocating	Revolving	Reciprocating	Revolving
Valve and rigid attachments	292	292			
Radius Links	90	45		45	
Drag Links	56	28		28	
Eccentric Rod and Strap	147	67	80	67	80
Eccentric Sheave	65		65		65
Totals		432	145	140	145
Virtual Primary Weights Reduction Factor $\frac{5}{220}$		96	33	32	33
Virtual Secondary Weights Factor = $\frac{5}{22} \times \frac{5}{52}$		2		1	
Crank ahead of Cylinder crank		135		225	

The only necessary change for the other valves will be in item 1. We then have all the information to enable us to add to the main gear polygons, lines covering the valve gear.

Estimating the Main Reciprocating Weights

These parts are the piston, piston rod, crosshead and the upper portion of the connecting rod, the last being found by assuming $g = 0.4$ (see p. 8). Secondary weights are found by multiplying by the connecting rod ratio $a = 1/4$. We then tabulate as follows — (these weights are for the I.P. as being the heaviest reciprocating weights).

Table 2. Maximum Main Reciprocating Weights

	Item	*Primary Weight*	*Secondary Weight (Reduction Factor of 1/4*
(1)	I P. Piston	615	—
(2)	I P. Piston Rod	200	—
(3)	Crosshead	300	—
(4)	Connecting Rod (Upper Portion).	380	—
	Totals	1495	374

The total of (2) (3) and (4), which do not change, remains 880.

Revolving Main Weights

These are the lower portion of connecting rod, the crank and the crank cheeks. The second and third are to be reduced to vertical weights which have their centre of gravity at the crank pin centre. This is done by multiplying them by the factor,

$$\frac{\text{Radius of centre of gravity of crank cheeks}}{\text{Radius of centre of gravity of crank pin}}$$

Table 3. Main Revolving Weights

Item	*Weight*
Crank Pin	200
Crank Cheeks (virtual)	350
Lower portion Connecting Rod	570
	1120

Procedure for Reciprocating Balance

The characteristic features of the four-crank balanced engine are:—

(1) Maximum reciprocating weights on centre cranks; these weights approximately being equal and from $1\frac{1}{4}$ to $1\frac{1}{2}$ times the mass of the two outer weights which are also nearly equal.

(2) Centre cylinders from 1.5 to 2 + times the distance apart of the outer cylinders.

(3) Cranks of forward pair at about 90° with cranks of after pair.

(4) Uneven crank angles.

The above values may be considerably altered, but only by adding considerable weight to the pistons and involving a large secondary couple.

From the diagrams of Taylor or Inglis we now find that arrangement of cranks which, with our given cylinder spacing, gives the least unbalanced secondary moment. This arrangement is as follows:—

$$\text{given} \left.\begin{array}{l} l_B = 0.242 \\ l_C = 0.716 \\ l_D = 1.000 \end{array}\right\} \quad \begin{array}{c}\text{Taking Reference Plane} \\ \text{through cylinder } A\end{array}$$

$$\text{Then} \left.\begin{array}{l} \theta_A = 65^\circ\ 50' \\ \theta_B = 267^\circ\ 50' \\ \theta_C = 160^\circ\ 20' \end{array}\right\} \quad \begin{array}{c}\text{Angles measured} \\ \text{forward from Crank D.}\end{array}$$

$$\text{and} \left.\begin{array}{l} \dfrac{W_A}{W_D} = 1.053 \\ \dfrac{W_B}{W_D} = 1.46 \\ \dfrac{W_C}{W_D} = 1.463 \end{array}\right\} \quad \begin{array}{c}\text{giving in terms of } C = 1495 \\ W_A = 1077 \\ W_B = 1491 \\ W_D = 1022\end{array}$$

This enables us to draw trial polygons for primary forces and moments including the valve gear, and secondary forces and moments, neglecting the latter which, as Table 1 shows, are very small.

A simple method is to draw separate valve gear polygons, thus obtaining the resultants due to them alone, using only these resultants which will not greatly change due to what small crank angle manipulation is necessary, checking the resultants before drawing the final polygons.

The object in drawing the secondary moment polygon which cannot possibly be closed is to be able to note the changes of the resultant couples due to changing weights and angles. The endeavor should be to keep this resultant a minimum. (Since all force polygons are to close, resultant moments will be independent of the position of the reference plane, i.e., they will be couples. Hence we may choose any point for the plane, preferably on a cylinder centre line).

Having now closed the polygons we scale off the weights from the primary polygon and compute them by adding weight to the various pistons. Thus the required weights of the three pistons are, (from Table 2)

H. P.	1460 — 880 = 580 lbs.
L. P.$_1$	1130 — 880 = 250 lbs.
L. P.$_2$	1065 — 880 = 185 lbs.

and the crank angles are as given on the diagram. The relatively small changes required due to inclusion of valve gear should here be noted: W_A being changed by + 53 lbs.; W_B by — 31 lbs.; W_C remaining unchanged, and W_D being changed by + 43 lbs., making a total of + 65 lbs.

θ_A is changed by $4^\circ 10'$; θ_B changed by $2^\circ 50'$, and θ_C by $4^\circ 40'$.

Revolving Balance

Revolving polygons are not shown, but there will now be no difficulty in obtaining revolving balance. Crank angles must not be disturbed, so balance is obtained by fitting counterweights to the foremost and aftermost crank cheeks. The farther apart these weights are placed the less they will, in general, have to be.

For a complete discussion of every phase of the problem of engine balancing the reader can do no better than to consult the Transaction of the Institution of Naval Architects of Great Britain and of the American Society of Naval Architects. All papers of any importance on the subject will be found reprinted in *Engineering*.

Hiawatha's Rodding

By E. C. EASY, C.E.
in "Engineer Clubman"

After Longfellow—A Trifle Footsore.

Skimped the huckleberry crop was,
All the other berries also.
Rasp-, and black-, and goose-, and whortle-,
Scant they were as tropic snowballs;
Not a square meal in a square mile;
Scarce as aluminium oysters,
Few almost as golden crowbars;
Not a deer in score leagues' distance—
Not a cat-fish, nor a dog-fish,
From the current could he cozen.
Not a catbird nor a titmouse,
From the forest could he ferret,
So that Hiawatha, hard pan,
Had got down to—good and plenty.
E'en for gulls' eggs was he hard up:
Sandbanks all suspended payment.
Naught of luck there seemed his portion.
Cold the summer, few the tourists,
Tourists to act guide to—shewing
Vacua to cast their bait in.
Empty pocket—Hiawatha's.
Up to him was now to hustle,
Railing the high cost of living.

Luck would have it then he chanced with
Engineers who shy of help were.

Hiawatha quick decided
That he'd give a moving-picture
Of an Indian plus some money.
He besought the chief of party:
"Give me of thy wad, O paleface,
Of thy pleasant plunks, O Big Chief;
Fain I woulds't toy eftsoons with 'em,
Much I like 'em for their crispness,
For their longness, also greenness,
For the picture-Indians on 'em;
For their scarceness, too, I love 'em—
Sparsely bank notes grow on bushes,
None too frequent in fat bunches."
Cinched the Indian, first thing offered.
So, behold you, Hiawatha,
New installed as rodding redman.
Careful heed he paid to, anxious,
All th' injunctions and advice notes
That the lev'ller put him over;
How to hold the rod straight upright
Parallel to 's major axis
When he stood erect—no cricks in
Shoulder—back, too, it all free from
Sneakish twists of wolf-rheumatics—
Verticality to rival.
Such the lesson, long, absorbing.
Taught he was, too, ne'er to slant it;
Nor to wave it unless signed to;
How to pick out stones and root-knobs,
Turning-points so they could serve for;
How to shape a bench-mark, ledge-like,
With his hand-axe on a green trunk;
Lots of cunning, saucy pointers
Hiawatha nailed whilst harking
To the lecture-leaking lev'ller.
"Snakes, I'll show him I'm no ninny,"
So thought Hiawatha, itchy
To get pay-day one day nearer.
" 'Tis a cinch, the job's a melon,
Pumpkin pies are toad stools to it;
I'll not let the long stick wobble,
Or some figures might drop off it.
As a rock I'll hold it steady,
Rock that lightning could not phiz on."
Broke to harness, Hiawatha.

Through some pretty bumpy country
Ran this trial-line we speak of;
Thick lay desperate gulches 'thwart it,
So that levelling no snap was—

Short the foresight, sawed-off backsight—
Difficult to read the hundredths—
Hard to see tenths indicated—
Feet in red most to be guessed at—
Trying to a Job's own temper
Was Smith's chauffage of his level—
Smith who took some flying levels—
Two legs mostly stuck 'way down hill
With the third poked towards high heaven;
Plates like clam shells when half-opened—
Swear-words quite facile of utt'rance
For the gent who shoved the level—
Yea, *some* hot uns—on the level!
But the twain kept right on at it—
Our friend Smith and Hiawatha—
Gad! Rewarded soon they felt like,
For, stretched out before them, shadowed,
Now they viewed a plateau pleasing,
Where the boles reared tall and stately,
Stately, fronding high, and yielding
Park-like vistas every-which-way.
Straight, long shots were here aplenty,
Far as telescope screwed good for.
Joyful he, John Smith, at field-work,
Knew his profile easier plotted
And the nicks between the high humps
Not in-growing, so deep-seated.
Thus the hog-back's plane they ate up,
Every second booking similar.

In this life, though, to an end soon
Everything in time doth come to:
Which was why they next confronted
One vast valley, most abyssmal.
Sheer and tangled were the hill-sides—
Windfalls, underbrush, all riot,
Like some canyon-wild, horrific—
Dante paints in his Inferno.
Smith he gasped quite—nearly throttled—
At the gulchy nightmare's viewing.
Was it safe to trust a long shot
'Cross the chasm far down below 'em?
Trust his level's high horse-power,
Trust the lenses' rare perfection?
Still, the more he rubbered downward
Past his toe-stubbed pair of shoepacks,
At the bally kind of riot
Strata, boulders, all seemed up to—
Typical of age Huronian—
More thought he to risk the chances—
Yep, sure Mike, he'd take a chance.

Hiawatha, so, he ordered
Down the depths to dip the dips;
Upward, then, to scale the rampart
Fronting where he had his set-up;
There to annex some good object
On the distant bank forninst 'em,
Fit to serve as bench-mark stable—
Rods behind him was the last one.
And addressed he, Hiawatha:
"Choose a good spot, Hiawatha;
Choose a pink-peach mark, O Indian;
That done can we hike for campwards,
Sneak, bee-line, for pan and kettle.
Soon will sun be low declining,
To his couch of red boughs sinking."
Nothing much spoke Hiawatha—
Language-vendor was he none of.
Down he clambered featly, thinking,
"This game's skin-tight to my measure;
This act I'll do scientific."

'Long about two-pipes-full later,
Smith, half-sleepy by his level,
Caught a distant whoop-la, proving
Hiawatha'd wriggled through it,
Spanned the fretful gulch between 'em.
Sprang to arms, did Smith, the lev'ller!
Spied to see the winking bubbles!
Swung the telescope twice crosswise,
Thumbscrews wooed he, wheedling, till he
Had all just-so for th' exposure!
Carefully his reading took he
Once and twice and thrice, ere booking;
Checked some more to see 'twas entered
Fair in virgin black correctly.
Last, he signalled his companion,
Waved him homeward o'er the gully.
Quit with work for that day was he;
Done was Smith, save for reducing.
Thoughts of frying pans he nurtured,
Thoughts of flapjacks toothsome in 'em,
Of the kettle's strong brew thought he.

Next morn, after strenuous labor,
Jamming shins and barking elbows,
At much cost of verbose temper
Smith and party, viz.: his rodman,
Reached at length the coign of vantage
Whence Smith was to, if per usual,
Make his H. I. diagnosis.

Faring onward, Smith had questioned
Hiawatha of his bench-mark.
Had he copped it well and truly?
Was it root, or stone, or bathbrick,
Had he smeared it well with red chalk?
Would he ken it from a puffball?
All such queries were projected.
Fine disdain were they received with.
Lo, the Indian seemed some touchy.
Smith, the leveller, thought it funny,
Verbiage grows, though not on 'Jibways—
He decided not to worry.
Now they'd won the sought-for station,
He, however, closer questioned;
Questioned for his pulse beat quicker,
Seemed to sense some hard-boiled blunder;
Asked the Indian quick to pipe him
Where he'd held the rod *last evening.*
Then it was that Hiawatha
Lent a baleful optic to him
And related how—not finding
Either rock, or stone, or such like—
He'd kidnapped an obese turtle,
Pressing hard his rod upon it;
Held it, plumbed it, waved it, raised it,
(Note: The rod's meant, not the insect.)
Keen obedient to the signals;
Then when big-waved O.K. backward,
He had found some string about him
And had tethered tight the turtle
To his sheaf-knife, earth-embedded.
Up and down, all higgl'y-piggl'y,
Lay the area could be skirt-danced
By that slackly snubbed-up turtle,
So that boy, nor man, nor woman,
Germ, nor beast, nor bug, nor microbe,
Might they tell within a 'phone-pole's
What said turtle's elevation,
E'en if na sae keen on rambling.
Crushed to earth, poor Smith, the lev'ller;
Gruff and silent Hiawatha.
Crushed to earth, Smith's brand new hat was,
For he camped and jumped—yelled—on it—
Something cruel, most egregious.
Gruff and silent Hiawatha.

This then is the tale so simple,
Told by Kagh, old Kagh, the hedge-hog.
This the tale how Hiawatha
Got the sack from railroad survey,

Forewent being rodman redman;
Beat it to his lodge-fire, hungred,
Touching only just the high spots—
All his fond hopes fair turned turtle—
Much cursed he the cost of living;
Swore to ring up old Nokomis
When he'd get the line not busy—
("Musquosh: Six-O-Four: 's the number.")
In the turtle-soup, sir, was he—
Nary 'mock' at all about it—
Hiawatha. ("Line still busy!")

THE ENGINEERING SOCIETY AND THE ALUMNI ASSOCIATION*

By T. H. Hogg, B.A.Sc.

There is little excuse on my part for venturing to address the Engineering Society at this meeting. When your president, Mr. Ritchie, requested me a few days ago to give you a short talk on the general relationship existing between the undergraduate and the graduate bodies of the Faculty of Applied Science, I hesitated, for since my association with the society, some few years ago, I have felt that the meetings of the society should be addressed only by men who might have something of definite value to present to the members. In thinking over the matter it occurred to me that perhaps a short resume of the history of the society during the past few years might be of some service, together with a few words on the present status of the Engineering Alumni Association.

As you probably all know, the Engineering Society has existed since 1885, about eight years after the founding of the School of Practical Science. I believe that Dean Galbraith, then principal of the School of Practical Science, was responsible in no small measure for the success attending its early years, as he has to the present been responsible for its continued existence and widened sphere of influence. Messrs. Herbert Bowman and T. Kennard Thomson were the undergraduates who actively promoted the society at its inception. Mr. Thomson has, through the past twenty-five years, remained one of the Engineering Society's best friends and one of the School's truest graduates. No labor is too great for him when the interests of the Faculty are at stake. The Engineering Alumni Association has many times called on him for his time and attention, and he has never failed to respond heartily. This is true, however, of a majority of the graduates, and I sincerely hope that it will continue to remain so.

Professor H. E. T. Haultain was the first student presi-

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*Delivered at a meeting of the Engineering Society, October, 16, 1912.

dent, for Dean Galbraith acted in that capacity for the first three years of the Society's existence. Since that time a long list of students has filled the president's chair, until in Mr. Ritchie you have your twenty-fifth president.

Many noteworthy events have taken place in the Society's history. The Engineering Society has always stood for the best interests of the students, the graduates and the Faculty itself. Perhaps no one is better fitted to give testimony to that than our Dean, and I am sure he will bear me out. I do not wish, however, to dwell on this history, as these remarks are preparatory only to what I desire to say.

It is necessary, however, before leaving its past history, to draw attention to one man who, perhaps, above all others, of the student members, has been responsible for the present strong position of the Engineering Society among University organizations. This man was Mr. K. A. Mackenzie, who was president in 1906-07. Mr. Mackenzie was president at what was one of the most critical times of the Society's history. The supply department, inaugurated a few years previously, had developed enormously, but was still being handled by a student secretary. The meetings were large and unwieldy, and it was difficult to obtain men to address these meetings on subjects of common interest. The graduates were rapidly increasing in number, and no attempt was being made to hold them together and keep their interest in the Faculty. The Transactions, issued annually, were becoming unwieldy, and were a heavy tax on the income of the Society. In fact, at that particular time the organization was in shape for trouble unless radical measures were taken to change the constitution. The changes that were made at that time, I believe, helped to place the Engineering Society in its present position, as one of the most powerful organizations in the University of Toronto, and as one of the most unique in the universities of Canada.

It was on Mr. Mackenzie's initiative that a new constitution was drafted, in which provision was made for sectional meetings, and for the appointment of a permanent secretary. With Mr. Mackenzie as the first permanent secretary, a new era dawned for the Society, and you gentlemen are reaping the results of that change of constitution in the magnificent supply department under your charge to-day. The next move was the changing of the Transactions of the Society into "Applied Science," a monthly publication, this again being due largely to Mr. Mackenzie. This move, together with the appointment of a paid secretary, has had a most far-reaching effect outside the undergraduate body. Its results are noticeable in the formation of the Engineering Alumni Association. Before that time no graduate organization existed. As a direct result of the changes above mentioned, and by the efforts of a few of the more enthusiastic graduates, the Engineering Alumni Association in Toronto was formed.

At the present time there exist Alumni Branches in Montreal, Timiskaming, Victoria, B.C., Pittsburg, New York, as well as in Toronto. This year it is hoped and expected that a few more may be founded in the West. The Toronto Branch of the Engineering Alumni Association has acted in the past as the central organization of the graduate body. While it is really only a branch, it has to a great extent molded the policy of the Alumni Association, and has freely called on the other branches of the Association for their support at critical times. As yet, there exists no permanent general Alumni Association, the Branch Associations now formed being really graduate bodies of the Engineering Society. Last year, with the idea of still more closely welding the undergraduate Engineering Society with the graduate Association, M. H. Irwin, your permanent secretary, was elected secretary of the Toronto branch of the Engineering Alumni. It is hoped in the future, as the organization develops, and an executive committee representing the whole graduate body is chosen, that your secretary will act as the secretary of the general committee. The Engineering Society was extremely fortunate, when, on losing Mr. Mackenzie's services a couple of years ago, it was successful in securing your present secretary. Mr. Irwin has done a great deal already for the furthering of the interests of both the undergraduate and the graduate, and in his present position is so located that he will be able to do a great deal more.

It is necessary to understand conditions some eight or ten years ago to properly appreciate the great amount of work which has been done towards organizing the graduate body, and I hope that these remarks will aid to a proper understanding of what has been done. The Alumni Association is to-day in a stronger position than it ever was before. The results are beginning to show in the scholarship fund, which is being furnished by the graduates for the founding of research scholarship in the Faculty. This year, as you know, at least one, and perhaps two appointments* will be made, and it is expected that each year hereafter two Fellows will carry on research work through funds furnished by the Alumni Association.

In closing these remarks it would not be fair to omit reference to the co-operation of the Dean and members of the Faculty in advancing the interest of the Engineering Society. At all times during its past history, the Dean has been close to the executive committees, guiding them with his advice and strengthening their hands by aiding in whatever changes in the constitution had become necessary due to the new conditions. The Dean has been responsible in no small measure for the unique position the Engineering Society holds in this Faculty.

I understand that there is some thought this year on the part of the executive committee to alter the custom relative to

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*These appointments, mentioned in September "Applied Science," have since received the sanction of the University Scholarship Committee, and the men are at work —Ed.

the annual dinner. The subject is one which merits discussion. The annual dinner is a function which has become a part of the life of the School, and I am sure that if it were dropped it would be the occasion of much regret on the part of the graduates. The dinner serves many purposes. Not the least among them is the fact that it is the only official occasion on which the Faculty and the Engineering Society come before the public. On the other hand, I understand that during the past few years the deficit in the dinner proceeds has become increasingly large and increasingly hard for the Engineering Society funds to handle. It may be that the time has come for a change to be made, but, personally, I sincerely hope that the executive committee this year can see their way clear towards preserving this annual function.

As a last remark, I would like to remind those members of the Engineering Society who are not in an official capacity, that in the year now beginning they co-operate in every way possible to help the present executive in carrying on the work of the society. As one who has been a member of the executive committee, I appreciate the amount of work which devolves on them. If you, as members of the Society, will only do your share, it is certain that the dinner will be preserved for this year, and that a new impetus will be given it which will do much towards securing its continued life.

DR. DUSHMAN

At the opening of the present session, Dr. Saul Dushman resigned from the position of lecturer in electro-chemistry to enter the employ of the General Electric Company at Schenectady, N.Y. His withdrawal is a matter of regret to both faculty and students, and the University has lost the services of an able investigator. Dr. Dushman, who is of Russian parentage, came to this country as a boy, and was educated at Harbord Collegiate Institute. He then entered the University, and, after a brilliant course, graduated in the Honor Department of Physics and Chemistry in 1904. He was immediately engaged as fellow for the recently created department of Electro-chemistry, and became in succession demonstrator and lecturer in this subject. Early in 1912 Mr. Dushman presented a thesis entitl d, "The Behaviour of Copper Anodes in Chloride Solutions," and received from the University of Toronto the degree of Doctor of Philosophy.

Dr. Dushman's enthusiasm has been an inspiration to his students, and he has been able to imbue them largely with his own ideals in scientific work. Gifted with an unusually alert mind, he has been able to keep abreast with the progress in other branches of science besides chemistry, and his broad reading has made him an interesting companion as well as an excellent teacher.

Dr. Dushman, while here, took an active interest in some of

the student societies and has been a frequent contributor to Applied Science as one of the associate editors.

He has entered the research laboratory of the General Electric Co. after spending some months during the summer in becoming familiar with the work. This laboratory maintained on an elaborate scale, and devoted to problems arising in the manufacture of the company's products, or to developing ideas into commercial possibilities, is famous for the high standard of the work which is carried on and for the success which has been achieved. Dr. Dushman will find ample scope for his abilities in his new position and his advancement may be confidently expected.

As an advisory on the Applied Science board, as an efficient and persevering instructor and as a close adherent to the ideals of University life and scientific advancement, Dr. Dushman will long be missed.

It will be remembered by readers of Applied Science that Dr. Dushman experienced the distressful misfortune of losing his wife early last summer. In deeply regretting his departure from University circles, it is felt that this sad occurrence may be not a little responsible for his disengaging from academic work and devoting his energies to the deep and thorough concentration of mind which research necessitates.

ENGINEERING ALUMNI ASSOCIATION FUNCTIONS

The Montreal Branch of the Engineering Alumni Association is holding its fall dinner on November 1st. It is expected that all the School men in that city and district will be in attendance. It is hoped that any other graduates who happen to be in the vicinity at that date will also notify the secretary, Mr. H. W. Fairlie, 1577 Mance St., Montreal.

The Temiskaming Branch of the Engineering Alumni Association is holding its annual dinner in Haileybury on Friday evening, November 8th. In the neighborhood of sixty graduates and undergraduates of the Faculty of Applied Science reside in the northern district, and it is expected that the majority of them will be at the dinner. The secretary, Mr. H. W. Sutcliffe, New Liskeard, and his Council, are making preparations for the most successful dinner ever held in Northern Ontario.

P. H. Stock, '09, is on railway construction work for the Niagara, St. Catharines & Toronto Railway. His address is St. Catharines, Ont.

F. W. Clark, '11, is in the employ of the International Waterways Commission, and is stationed at Niagara Falls, N.Y.

E. A. Kelly, '11, is located in Winnipeg and is engaged on construction work for the Canadian Pacific Railway.

A. I. Davis, '09, is in Ottawa, Ont., as salesman for the Canada Foundry Co., Ottawa Branch.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published every month in the year by the University of Toronto Engineering Society

SUBSCRIPTION RATES

Per year, in advance $2.00
Single copies 20

Advertising rates on application

Address all communications:

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

EDITORIAL

THE HIGHER STANDARD OF ENTRANCE

The Department of Education enacted a vital measure when it stipulated senior matriculation as the required standing for our prospective first year men. The announcement was made several years ago and the clause came into effect at the opening of the present term. It is the controversial opinion that the School has made an important advancement thereby. It will admit only men who have the training which a year or more in the higher form of the High Schools gives. They will come with better established purposes—bent upon securing all that their investment in an engineering education is capable of giving.

For a number of years the fact has been noticeable that the Engineering course is occasionally chosen by men for other than their firm conviction that engineering is a profession they intend to follow. It is frequently a matter of association rather than one

of definite purpose. This is detrimental to the welfare of the School as its output suffers a lowering of standard thereby. The new regulation will tend to bring a class with a better conception of the field before them. The curriculum will be put to a severer test and will be condensed and revised accordingly; several subjects now requiring time and lecture space in the first year time-table being eliminated, or replaced by others now drawing upon the time allotted to the second year, and so on. The entire engineering time-table will require altering, and in the desired direction.

The chief effect this year is in the reduced attendance. The first year is barely half its usual size. At the present writing (Oct. 24) the attendance by years is as follows: first year, 143; second, 205; third, 173; and fourth, 121; total, 642.

Not of least importance is the effect produced upon the sale of supplies in the Society's supply department. The decrease of 130 in the first year causes a proportional decrease in sales. Owing to the effect of the new requirement being much greater than anticipated in any quarter, the result may be summed up by the statement that, except in the supply department shelves and cases, no crowding obtains this year in the old Engineering Building.

THE NEW STRUCTURAL ENGINEERING OPTION

With the object of affording students in civil engineering an opportunity of acquiring special training in the design of structures, there has been inaugurated, in the Faculty, a Structural Engineering Option in the Fourth Year. It was recognized that a civil engineer in varied employment finds a knowledge of structures required of him perhaps more frequently than in any other department of engineering. So extensively do structures of one kind or another—bridges, buildings, foundations, retaining walls, dams, towers, tanks, flumes pipe lines and analogous constructions—enter into the carrying out of engineering projects, that a thorough acquaintance with the principles of structural design is practically indispensable to the civil engineer. The new option will particularly appeal to those who desire to fit themselves for designing or constructing engineers, or who contemplate entering the contracting field later on

The curriculum differs from that followed by other civil engineering students only in the fourth year. Certain subjects are also obligatory on all students in civil engineering in the final year, and of these some are of particular interest to those following the Structural Engineering Option. The obligatory subjects are Foundations, Electricity, Thermodynamics, Geology, Contracts and Specifications, and the writing of a Thesis on a subject selected by the student and approved by the Council. The course on Foundations consists of some twenty-four lectures on the theory and methods of construction of abutments, piers, footings, retaining walls and dams, with some practical problems of design worked out in the draughting rooms. Contracts and specifications, of

particular interest to the constructing engineer, are discussed in twelve lectures.

The elective subjects, now made available to those choosing the Structural Engineering Option are as follows:

Theory of Structures. A lecture course of about 48 lectures on so-called higher structures, such as swing bridges, arches, and suspension bridges. This is accompanied by the working out of several problems of design in the draughting rooms.

Strength and Elasticity of Materials. A laboratory course in the elastic and physical properties of the materials of construction, occupying, in all, some 144 hours.

Iron and Steel. In this course of about 24 lectures are discussed the relations between the composition of irons and steels and their physical properties. Some corroborative work is done in the laboratory.

Reinforced Concrete. A lecture course of some 24 lectures accompanied by the application of the principles learned to the design of reinforced-concrete floor panels, columns and girder bridges in the draughting rooms. This course covers the analysis of the monolithic arch by the theory of elasticity.

Structural Design of Buildings. A lecture course of 24 lectures accompanied by draughting room exercises in the design of building structures of timber, steel and reinforced concrete.

Mill Building Design. A course of some 24 lectures accompanied by work in the design of mill buildings, or portions of them, in the draughting rooms, The selection of type and the choice of the proper materials of construction to use are given special attention.

While the new course began with the present session, considerable interest has already been evinced in it, some 24 men having elected to take the option offered.

RESEARCH SCHOLARSHIPS

The Engineering Alumni Research Scholarships are both under way. The Faculty Committee approved of the awards and the men are at work. The Association is fortunate in having the co-operation of the staff of the Faculty of Applied Science in its scholarship movement. Their appreciation of the goodly aim and an assurance of their confidence has been evidenced by the great interest they have taken in the commencement of actual work. Their willingness to assist is most encouraging. Professor Rosebrugh has allotted desk and study room to Mr. Dobson in his own private office. Mr. Shaw has likewise been favored with office room in the Chemistry and Mining Building. Library facilities are open to each. Dr. Ellis, Professor Bain and Dr. Boswell, on Mr. Shaw's behalf, and Professors Rosebrugh and Price, upon that of Mr. Dobson, are giving all possible assistance. In short, the Fellows are not lacking in any detail from accommodation and opportunity at the hand of the staff of Applied Science.

When the date of the twenty-fourth annual dinner came up for discussion at a recent meeting of the Engineering Society many opinions were expressed. Owing to the heavy drains the dinner has made upon the Society's resources during the past years, it was felt that such another should not be experienced again this year, and a decisive stand has been taken with regard to the renowned annual event. The monstrous dinner deficits of past years are without doubt the results of one Dinner Committee determining to outshine its predecessor in the magnitude and grandeur of its aim. If this is continued the dinner's good name among the social events in the University is going to be lowered. No other function, except perhaps the Engineering dance, has paralleled it in the past. It has been of great value to the Faculty and to the University, but there is such a thing as needlessly overstepping the mark in attempting to enhance its measure of success.

THE ANNUAL DINNER

The School dinner is primarily for the School man, student and graduate, and the success of the affair will in future entirely depend upon his own inclination. To the undergraduate it is a yearly opportunity to spend a congenial evening in association with members of the Faculty in social frame of mind with academic manners and methods discarded, and of graduates who attend for the sake of old times, old themes, old jokes, and old faces, more than anything else. This means more to the student than he is capable of realizing at the time of the event. Always while a student, he should look forward to his graduation, and he should endeavor to gain the acquaintance and the interest of graduates who are years his seniors in Engineering—else when he graduates he finds himself a stranger entering the portals of the profession.

The stand which the Dinner Committee is taking with reference to making the affair a financial success should be endorsed by every student as it is to his interest more than to that of anyone else that the funds of the Society be not drawn upon on such occasion, but that they be conserved for more appropriate and beneficial use.

It is quite probable that the annual dinner will be held in December this year, to avoid a crowding of social events into the Easter term. The exact date has not been definitely decided.

BOOK REVIEW

The Theory of Machines, by Professor Robert W. Angus, University of Toronto. The University of Toronto Engineering Society, publishers. Cloth, 6 x 9 ins., 232 pages, 147 illustrations; $3.00.

As the title of this book suggests, it deals with the general theory underlying the construction of machines, and also with the application of the theory to the construction of actual machines.

In general in machine construction two distinct problems face the designer, the one dealing with the motions in the machine, the

effects of altering the proportions of various parts, such as crank and connecting rod in an engine, the effect of accelerations in the parts, and all similar problems. The other problem dealing with the proportioning of the parts is the science of machine design, the forces acting in the various parts being known and the parts being made of sufficient size to withstand these forces.

As Professor Angus has pointed out in the preface and is borne out by the book itself, problems of the first kind are those dealt with. In the first chapter the nature of the machine is carefully examined, the characteristics which it must possess, the relations of different forms of the same general construction and the connection between such machines as the steam engine, the oscillating engine, the Whitworth quick-return motion and other mechanisms.

The second and third chapters deal with the very important questions of motion and velocity in machines. The methods of finding the velocities of different parts of machines and of plotting these velocities are discussed in some detail, and the application is made to the determination of piston velocities and the rates of discharge from one, two and three throw-pumps.

In chapter four is discussed a very simple and useful method for determining velocities in the most complex machines by an easy practical construction, which is here published in detail for the first time. The method is illustrated by finding the velocity of the valve for a given setting of a Stephenson link and also by other problems.

Chapters five, six, and seven deal with toothed gearing. A comparison is first briefly made with other forms of gearing and then the proper form of the tooth outline is fully discussed and the two important forms, the involute and cycloidal, are investigated together with a comparison of their merits. The proportions of the teeth are also examined from the standpoint of motion, the strength not being considered.

Bevel gears are next being taken up in chapter six, the first case being where the two shafts intersect, giving the ordinary form of bevel gearing. A very common and difficult case is next examined, i.e., where the shafts do not intersect such as in the case of the crank and cam shafts of many gas engines. This gives rise to two forms of gearing depending on the desire of the designer, the first form being where large amounts of power are transmitted and hence where line contact is required between the teeth, while the second case deals with the worm and wheel in which there is a point of contact. The former problem, while complicated in theory, has been reduced to a most simple graphical construction for finding the dimensions of the wheels.

This is followed by the chapter on the trains of gearing in which the application of the gears to various machines is taken up. Such a machine as the screw-cutting lathe is taken as an example and the gearing is calculated. The epicyclic train for very high velocity ratios is also examined and illustrated in such a case as the Weston triplex block. Numerical examples and designs have been given here.

Chapter eight deals with cams and their construction and the method of laying them out.

In chapters nine and ten the effect of forces in machines is examined, the force at the crank required to crush the stone in a stone crusher, the same problem for a shear actuated by a cam, the turning moment on an engine due to the steam pressure, etc. In the latter problem the indicator diagram is taken and from it the turning moment is computed and plotted, and the relative merits of tandem and cross-compound engines, etc., form this point of view, are discussed.

The efficiency of machines is treated in chapter eleven and application made to several important machines, among which is a governor and a steam engine.

The next chapter treats of governors and examines the principles of construction and the determination of the weight of governor balls, etc., to fulfil given conditions. A method is here introduced which should be of great help to the designer, and a problem is solved in the design of a fly-ball governor to satisfy given conditions of speed, powerfulness and sensitiveness. The shaft governor is also studied and the general conditions to be fulfilled fully discussed as are also other forms of spring governors.

Chapters thirteen and fourteen deal with speed fluctuation in various machines and the methods adopted for controlling them. The method of computing the fluctuation for any machine is fully discussed and applied to the case of an engine where a numerical example of an actual case is worked out in detail. The same thing has been done for a gas engine.

The determination of the weight of the fly-wheels is made by a new method which it is believed is very useful and also numerical examples have been worked.

The last chapter treats of the accelerations in various parts of machines and the effect of the accelerating forces on the stresses in the parts and the pressures at the bearings as well as their effect on the turning moment. A numerical problem has been solved to illustrate the method.

The entire book attempts to deal with the machine theory from a general point of view, graphical methods have been used almost entirely, as the drafting board is always at hand for the engineer, and whatever theory has been introduced has been used rather as a means to an end, the graphical constructions usually being simple enough to be used by anyone not understanding the theory.

The book is the largest and most important of all the Engineering Society's publications.

M. B. Hastings, '10, until recently with the Toronto Hydro-Electric system, has accepted a position with A. H. Winter Joyner, Limited, Toronto, as sales engineer.

P. T. Kirwan, '10, is engaged as chemist at Capelton, Que., with the Nichols Chemical Co.

[illegible]